It's Critical: Student Attitudes toward Critical Thinking and an Assessment of a Lecture to an Introductory Engineering Class

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Abstract

Critical thinking is an essential skill for achievement as an engineering student and for success in the engineering profession. Critical thinking can be defined as a mental process to responsibly form an unbiased conclusion that includes identification, skillful analysis, and evaluation of evidence to guide decision-making. This article evaluates a research project undertaken by students at the University of San Diego. In the investigators' work, they analyzed the definitions of critical thinking and bias, what tools could be used to help in the critical thinking process, and how concepts such as bias and critical thinking affect engineers in their occupations. The team then presented this information to several introductory engineering classes in the form of a lecture and asked the students to assess their knowledge and understanding of critical thinking concepts before and after the presentation. The investigators evaluated the surveys and discovered that most students improved their definitions of bias and critical thinking after the lecture. The students also generally improved their self-rating of understanding critical thinking concepts.

Keywords: Critical Thinking; Skillful Analysis; Bias; Engineering Education

Introduction

This study was conducted by the Introduction to Engineering Design honors section (Engineering 102H) at the University of San Diego (USD). Engineering 102 is an introduction to engineering design practice course, overarching the three engineering majors USD offers; electrical engineering, industrial and systems engineering, and mechanical engineering. The primary difference between the honors section and the regular section is that students in the honors section meet one additional hour per week to discuss and research the topic of critical thinking.

Definitions of Critical Thinking

As this project deals with concepts and understanding of the term critical thinking, the team decided to first formalize its definition. However, definitions of critical thinking vary greatly, from short and simple definitions, to longer and more complex definitions with words describing every facet of thinking

critically. For example, The National Council for Excellence in Critical Thinking (1987) states the definition for critical thinking as:

> "Critical thinking is the intellectually disciplined process of actively and skillfully conceptualizing, applying, analyzing, synthesizing, and/or evaluating information gathered from, or generated by, observation, experience, reflection, reasoning, or communication, as a guide to belief and action. In its exemplary form, it is based on universal intellectual values that transcend subject matter divisions: clarity, accuracy, precision, consistency, relevance, sound evidence, good reasons, depth, breadth, and fairness."

Although this definition is rather long, it is easy to see that some of its major themes are "objectiveness" and "thorough analysis." It is also interesting that critical thinking is referred to as a process for the purpose of being a "guide to belief and action," showing that critical thinking can and should apply not only in the classroom, but everywhere.

The Delphi Report (Facione, 1990) provides a somewhat simpler definition, but keeps some of the major concepts, defining critical thinking as:

> "purposeful, self-regulatory judgment which results in interpretation, analysis, evaluation, and inference, as well as explanation of the evidential, conceptual, methodological, criteriological, or contextual considerations upon which that judgment is based."

Again, the terms "analysis" and "evaluation" are mentioned, but this time the definition also mentions "self-regulatory judgment" and "interpretation," implying there is human error involved within the process, perhaps in the form of bias, despite being methodological or evidential.

The Critical Thinking Co. (2005) much more succinctly defines critical thinking:

> "Critical Thinking is the identification and evaluation of evidence to guide decision-making. A critical thinker uses broad in-depth analysis of evidence to make decisions and communicate his/her beliefs clearly and accurately."

Again, "analysis" is mentioned as a major idea, but the key here is that critical thinking is most simply a guide for decision-making (which also implies that critical thinking is a tool for every aspect of daily life). It is also important to note that this definition includes "communication," which indicates the importance of other parties being involved in the critical thinking process.

It seems that the major ideas expressed in these various definitions of critical thinking were analysis or evaluation of evidence, judgment (indicating the presence of bias), and usefulness in the form of a decision making process. Based on this survey of previous definitions, two students from the Engineering 102H class established their own definition for critical thinking as the following:

> "Critical thinking is a mental process used to responsibly form an unbiased conclusion that includes skillful analysis, identification, and evaluation of evidence to guide decision-making."

The research team felt that this definition encompassed the major ideas from the definitions encountered, without being too lengthy or complicated. It incorporates the concept of bias, and includes the terms "responsibly" and "skillful," which point toward the precise and careful nature of critical thinkers. This definition also mentions the simple use for it, as a guide to coming to conclusions, and lends to the idea that "evidence" and its analysis is what drives the decision-making process. It is for these reasons that this student definition of critical thinking was chosen as the official definition to be used by the team, and the remainder of this article will reference this definition when referring to the term "critical thinking."

Applications of Critical Thinking

Critical thinking can be applied to a variety of fields, and the article by the University College Dublin provides some information specific to linking critical thinking with science, technology, and engineering (Ahem, n.d.). The article postulates that critical thinking is especially crucial in engineering, as engineers must come up with innovative solutions to problems such as "provision of sustainable transport, infrastructure, or clean water supplies." The article asserts that critical thinking is vital because it is, at its core, a problem-solving strategy. The writers point out that an engineer does not only have to deal with the calculations and numbers, but also the social factors and possible impact on the community that a decision might have. It continues to describe that the goal of creating good critical thinkers can be achieved by "cooperative learning, problem based learning and ensuring that students engage in meaningful learning activities in order to encourage more critical and reflective thinking." Lastly, the article mentions how critical thinking is extremely important when considering which attributes employers see as valuable.

Teaching Critical Thinking

Research has shown that critical thinking is not only very broad, but is pivotal for those in STEM fields (science, technology, engineering, and mathematics). Teaching it, however, and getting others to think critically, is another issue in its own entirely. There have been many studies on critical thinking, and people have created numerous techniques for teaching it. One of the most popular examples is Toyota's "5 Why's," developed by Toyota Industries founder Sakichi Toyoda, where one repeatedly asks themselves "why" a problem has emerged ("Determine the Root Cause", n.d.). This is an effective way to teach critical thinking because it teaches students that identifying the root of a problem is more effective than fixing the problem directly just for it to occur again. It also gives students a technique they can use to easily identify the root problem.

Grant (1988) emphasizes to not actually teach students what critical thinking is, but ways to get students, specifically high school students, to think critically about a given subject at hand in the classroom. She

looks at a few well-established high school teachers in English, History, Physics, and Government, and analyzes their methods of engaging students. Often Grant analyzes specific approaches and she makes it clear that, regardless of subject matter, writing out thought processes (or related writing in general) contribute to intellectual thinking. Thorough discussion of topics and correction of erroneous thinking are of importance as well. There also has to be a motivation within the students to *want* to learn, or else the goal of teaching them to think critically becomes unachievable, as learning opportunities require active participation to be effective. Finally, communication between the teacher and student ensures proper transfer of information and therefore, ideally, the ability to think critically. The means of communication, though, may vary largely depending on subject matter or context of the situation, Grant asserts. In order to get students to comprehend and to engage, different modes of teaching may be brought about, such as group projects, debates, or other types of classroom organization to get students to focus on a topic. Finally, Grant talks about the different types of knowledge a teacher must have, including the knowledge of the subject, knowledge of what the students know, and the knowledge of oneself and one's own limitations.

There have been a large number of other studies on effective ways to teach critical thinking and critical thinking skills. It has been concluded that these skills are not effectively taught through the normal curriculum classes. When it comes to teaching critical thinking directly, it has been shown that there is a significant increase in critical thinking skills in students who took a class where critical thinking was explicitly taught (Bensley, Crowe, Bernhardt, Buckner, & Allman, 2010). Courses where critical thinking was a not a direct objective, but "CT [critical thinking] is regarded as a by-product of instruction, had the smallest effect" and courses "where CT is taught as an independent track within a specific content course, had the largest effect" (Abrami et al., 2008).

It has been found that professors of non-technical subjects such as in the humanities are very aware of critical thinking, and make a great effort to teach students how to think critically in their classes. On the other hand, technical subjects, including chemistry and engineering have so much information for the students to learn that, although professors consider critical thinking when teaching their courses, there is often no room in the curriculum to teach it directly. Because of these reasons, professors in technical subject areas were often unsure of a clear definition of critical thinking, while other professors had put a substantial amount of time into understanding what critical thinking is and how they can teach it in their course (A. Ahern, T. O'Connor, G. McRuairc, M. McNamara, and D. O'Donnell, 2011).

Institutional Review Board (IRB)

The first step toward receiving IRB approval for the human research project was to have every member of the research team complete an online IRB training course. The course outlined ethical concerns of past research experiments while explaining what is acceptable under the IRB guidelines. It lasted about two hours and consisted of multiple sections applying to everything from history to privacy concerns. After completion of the course, each member of the group received an official certificate verifying their

completion of the course. The newly certified members could then be added to the research study as Co-Principle Investigators, and the Principle Investigator was selected based on their outstanding knowledge of the subject.

After confirming that every researcher in the group was qualified to give the presentation and administer the research study materials, it was important to outline how the research would be conducted. The researchers attached the survey materials developed in class, while outlining the procedure for delivering the surveys and the lecture to the student subjects, and the team's plan for analyzing the data collected with the surveys. In order to make sure that the participants were well informed, the research team included a form to be signed by the subjects explaining any possible risks involved, and stated that the information collected would be completely anonymous. The incorporation of the risks, benefits, and privacy issues were a key factor in completing the IRB proposal and ensuring that the IRB would pass the proposed study.

STUDY APPROACH

In order to conduct the study, the research team presented a lecture about critical thinking and bias to several other Engineering 102 classes and asked the students in those class sections to complete surveys both before and after the lecture regarding their understanding of the concepts. Once the surveys were collected, the data was analyzed to determine if there was any change in the subjects' comprehension of the topics. The following is an overview of the lecture materials that were used in the critical thinking research project entitled "Think Critically." The lectures were conducted by the Engineering 102 honors section at the University of San Diego on April 22, 2013.

Description of the Critical Thinking Presentation

The lecture began with a group of three to four honors students introducing themselves as well as the title of the project, "Think Critically." This first slide, although it contained no educational material, was designed to spark interest. The picture on this slide, a "thinking" brain, went a long way in getting the audience to "turn on" their brains and consider what the presentation might be about. The table of contents slide, a slide that was immensely important to the whole presentation, shortly followed this. It gave the audience an overview of what would come later in the presentation. The goal was that an audience member would be able to relate something they saw in the first slide to their own life.

Before starting the 'Think Critically' lecture, the presenters displayed this riddle:

> *A father and his son get in a car accident, in which the father is killed and the son is badly hurt. The son is quickly rushed to a hospital. When the boy is taken in for an operation, the surgeon says 'I cannot do the surgery because this is my son.' How is this possible?*

Because some students might have previously heard this riddle, the presenter asked the students not to respond if they already knew the answer before asking any more questions about it. This is to ensure that

all students could take time to think about this riddle and answer. After giving students a minute, the presenter asked for any possible answers from students who had never heard the riddle before.

After hearing five to seven answers, the presenter revealed the answer: the doctor is the boy's mother. The presenter then explained that this riddle uses critical thinking because students are required to think of what information is needed to find the answer. This warm up activity was a way of engaging the students to the lecture material as well as encouraging student participation during the lecture.

Definition of Critical Thinking

The second activity of this presentation was the definition of critical thinking. On the slide, the presenter showed a picture with words related to thinking critically. Instead of giving students the definition immediately, the presenter asked students to form a group of two and to write their definition on the board. The presenter then went over the definitions on the board and mentioned similarities and differences between the answers. After listening to the students on what they think critical thinking is, the presenter shared the definition that the Engineering 102 honors students composed:

> *Critical thinking is a mental process to responsibly form an unbiased conclusion that includes skillful analysis, identification, and evaluation of evidence to guide decision-making.*

The presenters also explained the tools to practice critical thinking such as FRISCO, which stands for focus, reasons, inference, situation, clarity, and overview (Ennis, 1996), and the 5 whys ("Determine the Root Cause", n.d.).

5 Whys Process

The "5 Whys," also known as the two-year-old rule, is a method to solving problems at their core as it requires critical thinking and skillful analysis to get to the root of the problem instead of only addressing surface level issues by keep asking the question "why" until the source of the problem is discovered. After explaining what the "5 Whys" process is, the presenters performed a skit that illustrates this method:

Person 1: Hey dude I got a flat tire on my bike... I'm so bummed! What do I do about it?
Person 2: Well...Why did you get a flat tire?
Person 1: There was a piece of glass on the road that ripped my tire.
P2: Why?
P1: It was parked by a bar where people drop glass bottles
P2: Why were you parked by a bar?
P1: Because my grocery store is next to a bar.

> P2: I HAVE A SOLUTION! You could change your tire, but if you want to solve the problem at its root, next time park on the other side of the grocery store and ride your bike away from the bar."

The presenter then explained how Sakichi Toyoda, inventor of this method, came up with the "5 Whys," and how this approach can be utilized by everyone, regardless of career choice, to critically solve problems with creative solutions. The "5 Whys" discussion was included in the lecture material as an easy to use tool for critical thinking. However, the restriction to a single lecture hour did not allow any further exploration or practice of this method.

Analyzing Sources

For this slide, the presenters first asked the students to give their opinions on what a "Martin Luther King Jr." website's content would be about (The Truth About Martin Luther King). Expected answers were along the lines of a biography of Martin Luther King Jr. or a civil rights website. The presenters opened the website and had the students open the website on their own computers, allowing them a few minutes to look over the website. Then the presenters asked the students what it was about, the main message contained in it, and whether they thought the website was biased in any way. After the discussion based on their observations, the presenters revealed what really was going on in the website. They asked for the students' thoughts about the website after learning the truth behind it: that a neo-Nazi group runs it. The presenters moved on to the second website about dangers of "di-hydrogen monoxide", also known as water, and asked if anyone knew what it is (Way). The similarities between this website and the Martin Luther King Jr. website were discussed in that it appeared to be one thing but was actually another. The presenter also discussed bias and explained how applying critical thinking is important so that information from the website is not taken mindlessly, but instead taken with evidence and sources from which the information is presented are processed and examined beforehand.

Ted Talk

The last activity in the presentation was a TED Talk, a nine-minute video shown to the audience (Eli Pariser: Beware Online "Filter Bubbles"). The presenters talked to the audience about being aware of online filter bubbles. This was meant to be without a definition to get the students thinking about what it is that the presenters mean. The presenters continued this preface to the video by asking some questions for the audience to think about in their heads before, during, and after the video to see if their opinion changes. The questions were: How do you use the Internet? Have you ever considered the fact that your searches are filtered? What do you think about the sources Pariser has to back up his claims? And also to consider the pros and cons of an Internet utilizing filtered searches tailored to your personal interests. The video was then played for the audience. During the video, Pariser talks about the mechanism in Google as well as in Facebook to show the users the links that its algorithm believes are the most relevant to the user based on dozens of factors from where the user is to what kind of search engine is used. He talks

about how two of his friends came up with completely different search pages on Google when typing in the exact same words. This is supposed to open the eyes of the audience because there are tons of people that do not know this is happening to them every time they make a search on the Internet. Pariser goes on to talk about how the information that is presented on Google is not always what we need to know although it might be relevant to what we want to know. He uses a metaphor that information is like food: everyone needs their information fruits and veggies (what they do not necessarily want to hear) as well as their information sweets (what they do want to hear). This analogy is meant to get the audience thinking on their "information diet" and for each audience member to be able to see if they are getting a balanced "diet." After the conclusion of the video the audience was asked to respond to the video by sharing comments that they had. In particular, the sources for the evidence presented by Pariser were examined.

Description of the Survey Forms:

The researchers made an effort to design a set of questions that would both quantitatively and qualitatively test the students' understanding of the subject material. This survey was developed with the intent to gain an understanding of how well the audience grasped and understood the presented information and concepts. As the focus of the study is on the concepts of critical thinking and bias, the survey did not directly query any of the hands-on methods presented in the lecture (e.g. 5 Whys).

Quantitative analysis included a set of five questions that asked the students to rate their understanding on a 1 to 5 scale, 1 being a very poor understanding and 5 a very good understanding. The survey asked the students to rate their perceived understanding of critical thinking and bias before the presentation was given. It also asked the students to rate themselves on their understanding of critical thinking and bias after the presentation was given. Lastly, the survey asked the participants to rate their understanding of the "5 Whys", after being part of the corresponding activity on the same scale. These quantitative questions were created in an effort to easily and numerically evaluate the success and failures of the presentation and presenters. The survey questions asked for a quantitative purpose were:

1. How well do you understand the concept of critical thinking on a scale from 1 to 5?
2. How well do you understand the concept of bias on a scale from 1 to 5?
3. How well do you understand the concept of critical thinking on a scale from 1 to 5?
4. How well do you understand the concept of bias on a scale from 1 to 5?
5. After being part of the "5 Whys" activity, how well do you understand the concept of the "5 Whys" on a scale from 1 to 5?

(1 = very poor, 2 = poor, 3 = fair, 4 = good, 5 = very good)

Qualitative analysis included a set of four questions. These questions, just as the quantitative questions, had both before and after components. Students' understanding of critical thinking and bias was tested again. This set of questions, though, required a more in depth answer. Participants needed to express their complete thoughts to answer the questions. The qualitative questions were created to pinpoint the language

and vocabulary used by participants in their answers. The Survey Questions asked for a qualitative purpose were:

- Define critical thinking in your own words.
- Define bias in your own words.
- Define critical thinking in your own words.
- Define bias in your own words.
- Why is "5 Whys" process important?

After receiving these responses, the research team analyzed the results.

Results

Before and after hearing a lecture on critical thinking, participants of the research filled out the survey to evaluate their knowledge on the subject and how the class was taught both quantitatively and qualitatively for the research team's purposes. The quantitative values from the surveys were then reviewed by a team to judge the fairness of the participants' ratings on their own answers to the questions. In order to evaluate the students' understanding of the concepts, the team reviewed their definitions on a specific topic and gave ratings.

The survey team purposefully asked the same questions twice to compare the participants' answers before and after the lecture to see the impact of the lecture on to participants. Because the participants were not exposed to the "5 Whys" process prior to the lecture, there was no corresponding question in the initial survey. For a quantitative review of students' understanding of critical thinking and bias, the survey team allowed students to rate themselves in a scale of 5: 1 very poor, 2 poor, 3 fair, 4 good, 5 very good understanding of the concepts. For a qualitative review, a program was used to create Worldes, which show the frequency that a word was used by its proportional size in the picture.

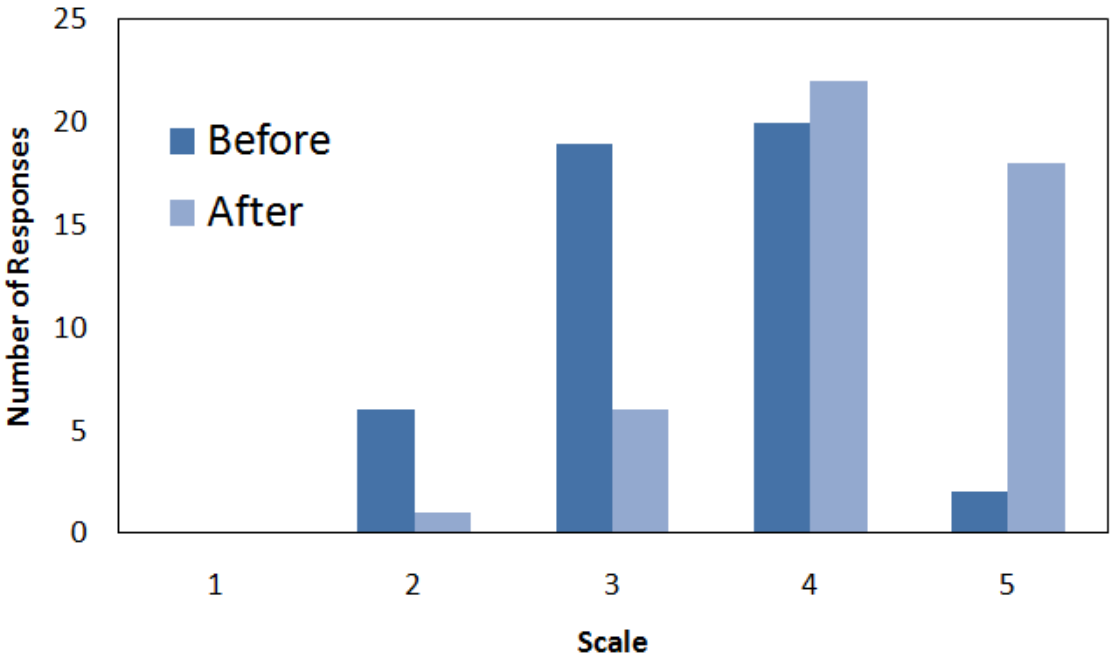

Figure 1: Histogram of student responses to the question "How well do you understand the concept of critical thinking?"

The histogram in Figure 1 compares the before and after the lecture responses on students' understanding of the definition of critical thinking. After analysis, the team observed that no one chose 1 or very poor as their understanding of critical thinking neither before nor after the lecture. As exemplified by the data, most students answered 3 or 4 before the lecture, while a majority answered 4 or 5 after the lecture, which demonstrates that their understanding of critical thinking increased from the beginning to the end of the presentation.

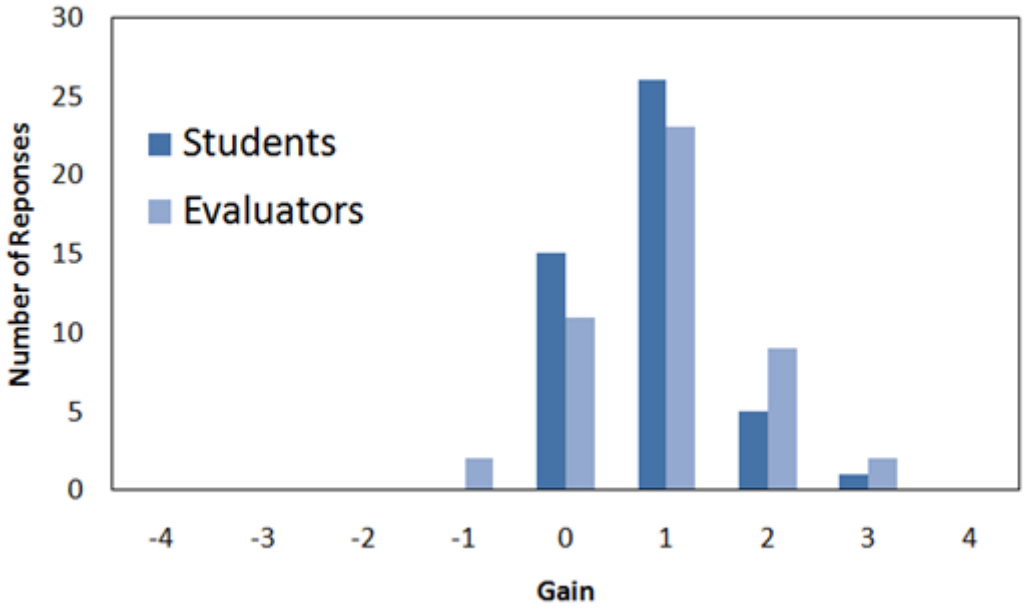

Figure 2: Histogram of observed gain on critical thinking from the lecture

The histogram in Figure 2 illustrates a general improvement in the confidence of students in understanding critical thinking. The vales for the histogram were derived by subtracting the ratings before the lecture from the score after the lecture. The research team observed the positive impact of the lecture on students from their evaluation on their understanding of critical thinking. Most students responded either no gain from the lecture in understanding critical thinking or one higher value than the initial rating. However, the average gain of +1 indicates that the lecture expanded the students' understanding of critical thinking.

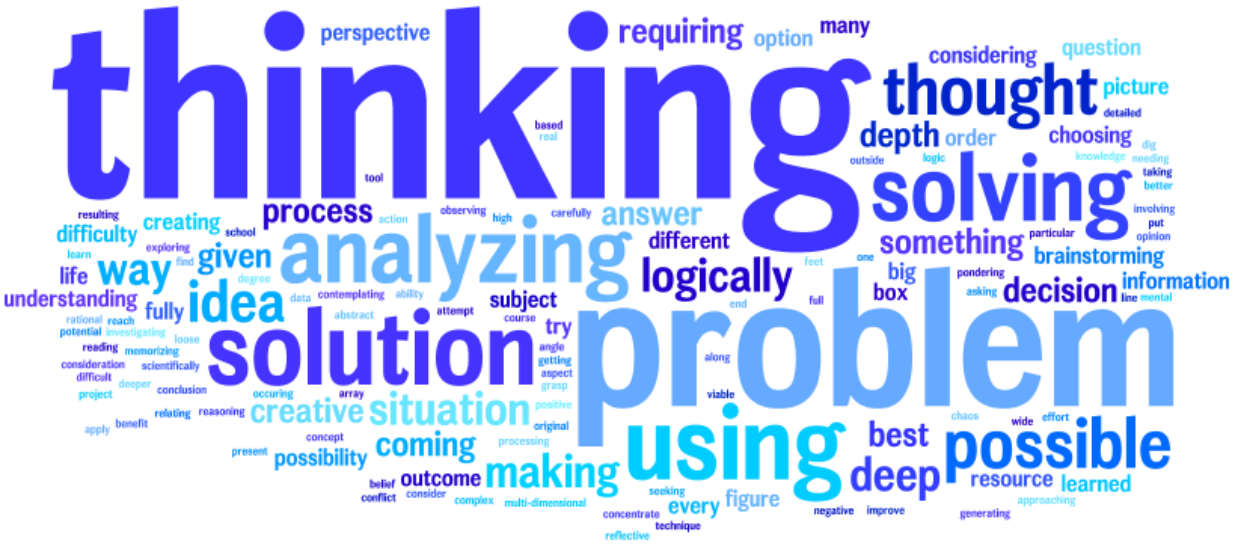

Figure 3: Wordle of students' definition of critical thinking before the lecture

The Wordle in Figure 3 shows that nearly every student used the word "thinking" in their definition, and nearly the same amount of students used "problem". The fact that these two words have such a high appearance in comparison to the other words indicates that students had a particularly narrow understanding of critical thinking.

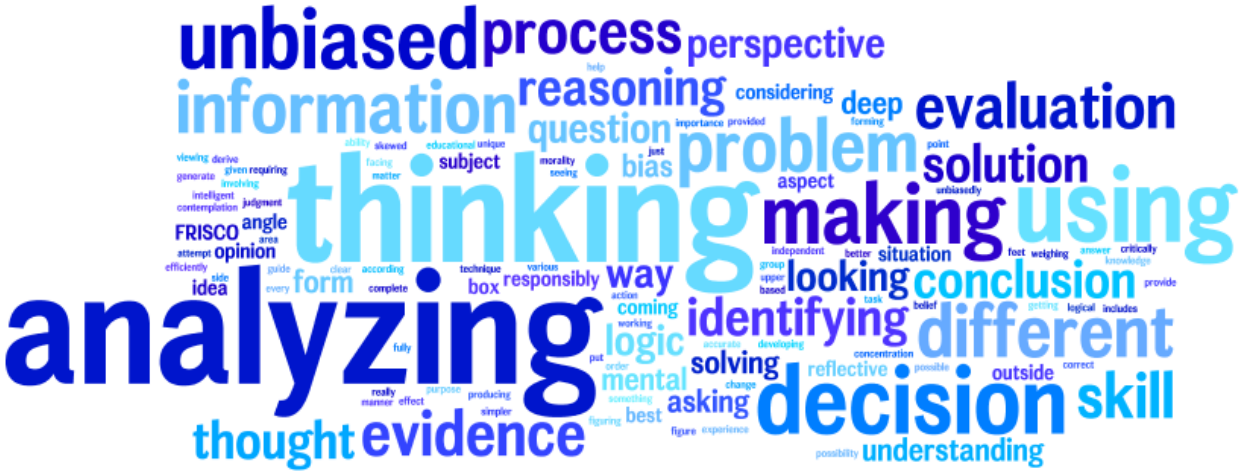

Figure 4: Wordle of students' definition of critical thinking after the lecture

The Wordle in Figure 4 exhibits the students' definitions of critical thinking after the lecture. There is a great increase in diversity of words used in this definition compared to the choices made before the lecture. In their initial definitions, students primarily used the words "problem" and "thinking" to define critical thinking, whereas after the lecture "thinking" is still the most used word, but other words such as "evidence," "unbiased," "analyzing," "information," and "process" are newly introduced, as exhibited by their proportional sizes. This expansion of word usage can be recognized as an increase in the understanding of the topic, as it illustrates that students now have a broader view of all the aspects that make up critical thinking.

The histogram in Figure 1 compares the before and after the lecture responses on students' understanding of the definition of critical thinking. The graph illustrates that students were more confident in their understanding of critical thinking after the lecture. The histogram in Figure 2 compares the gain of students' understanding of critical thinking as rated by students and researchers. The positive values demonstrate that both the researchers and students observed improvement of the students' understanding of critical thinking from the lecture. This improvement is also shown in the Worldes. The increase in diversity of words used shows that they now see it as a broader topic than they had before, and understand that there are many different aspects of the subject. Many of the words seen in Figure 4 are similar to words used in the lecture, showing that the students had absorbed the information presented to them.

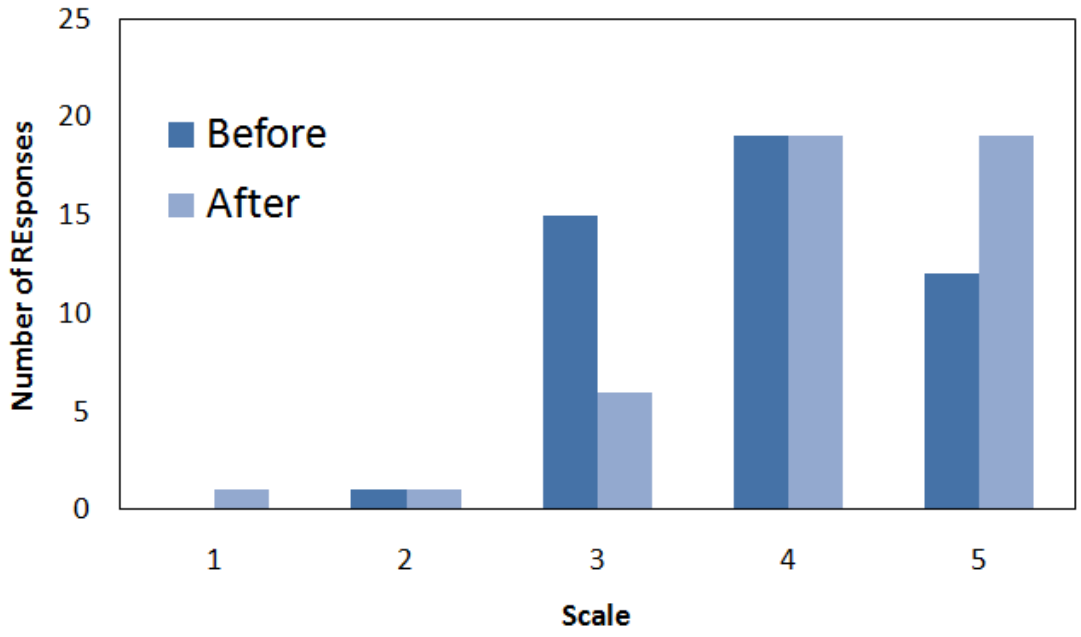

Figure 5: Histogram of student responses to the question "How well do you understand the concept of bias?"

The histogram in Figure 5 compares the students' rating on their understanding of the definition of bias before and after the lecture. The researchers observed that this histogram looks similar to the histogram in Figure 1. Most students scored between 3 and 4 before the lecture and 4 and 5 after the lecture. However, the team also observed that someone rated their understanding of bias as very poor after the lecture, indicating that the lecture may have had a negative impact on select students. The graph also indicates that students were generally more confident in their understanding of critical thinking.

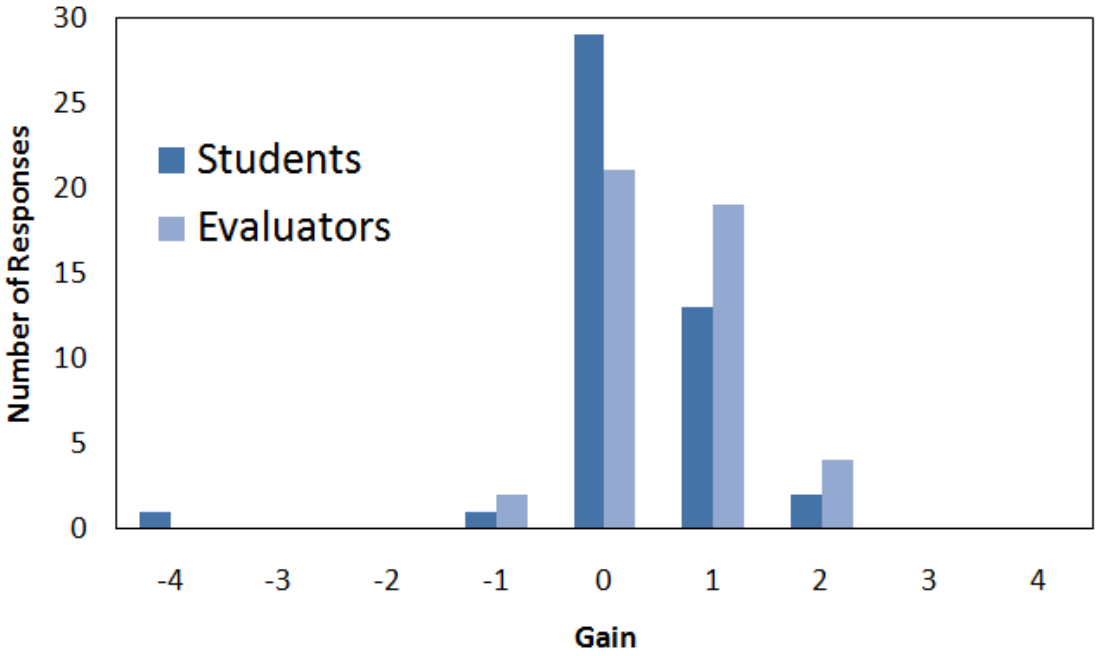

Figure 6: Histogram of observed gain on bias from the lecture

The histogram in Figure 6 illustrates that there is a general improvement in the confidence of students' understanding of bias, even though a decrease in confidence level is also present. Most students responded with no improvement in their understanding of the definition of bias, which may show that the lecture have not been geared toward the concept of bias, but more focused on critical thinking. The graph also shows that the researchers observed more improvement in understanding of bias from the lecture, while the students did not perceive an improvement in their understanding.

Figure 7: Wordle of students' definition of bias before the lecture

Wordle in Figure 7 shows that the three words used most to define bias before the lecture were “one”, “opinion” and “side”. The fact that most students utilized these three words illustrates that they have a very limited understanding of the subject, and do not comprehend all of its implications, such as bias due to previous experience.

Figure 8: Wordle of students’ definition of bias after the lecture

A similar trend is shown in Wordle in Figure 8 as was seen in Wordle in Figure 4, which displays the increase in words used in the students’ definitions of bias after the lecture. In the pre definition of bias, nearly every student used “opinion,” “one,” and “side”. In the post definition, words such as “based,” “toward,” “favoring,” and “prejudice” are shown to be more frequent. The increase in the diversity of words employed to define bias demonstrates that students had come to recognize that it is a much more complex subject than they had initially believed it to be.

The histogram in Figure 5 compares the students' rating on their understanding of the definition of bias before and after the lecture. The histogram in Figure 6 compares the students’ and researchers’ ratings on gain of students' understanding of bias. The graph reveals that there is a general improvement in the confidence of students' understanding of bias, even though a decrease in confidence level is also present. The graph also illustrates that the researchers observed more improvement in understanding of bias from the lecture, while the students did not perceive an improvement in their understanding. A similar trend is shown in the Wordle in Figure 8 which displays the words used in the students’ definitions of bias after the lecture. The sizes of the words are much more balanced, showing that there was an increase in the amount of words used in the survey and that the students had gained an expanded understanding of the subject, matching the trend shown in the histogram.

CONCLUSION

It was observed that on average the students' understanding of critical thinking along with their understanding of bias increased both on a numerical scale and in the diversity of words associated with the topics. The understanding of the students was viewed through the surveys' before and after components. The review of the surveys made apparent that the definitions given for both critical thinking and bias by the students in the initial surveys used a very limited vocabulary. This showed a limited understanding of the subject. However, the post survey definitions utilized a much more diverse group of terms, mirroring the increase in understanding of the topics highlighted in the lecture and demonstrating that the students now saw the topics as being more extensive than they had initially defined them to be. This change could be attributed to the work of the researchers and presenters. Their effect on the students showed through the terminology and examples within the students' post survey responses. Many of the terms used in the post surveys were similar to those given in the lecture either verbally or visually, exhibiting the fact that the students were retaining some of the information given and understanding it well enough to apply it to a definition. The qualitative and quantitative results of the surveys showcased the success of the researchers' lesson. Therefore, the methods and examples within the lecture were also concluded to be used in a successful manner.

REFERENCES

Abrami, P. C., Bernard, R. M., Borokhovski, E., Wade, A., Surkes, M. A., Tamim, R., & Zhang, D. (2008). Instructional Interventions Affecting Critical Thinking Skills and Dispositions: A Stage 1 Meta-Analysis. *Review of Educational Research*, *78*(4), 1102-1134.

Ahern, Aoife, Dr. *Critical Thinking in Science Engineering and Technology*. *Ucd.ie*. University College Dublin, n.d. Web. 9 May 2013. <http://www.ucd.ie/t4cms/critical%20thinking%20in%20science%20engineering%20and%20technology.pdf>.

Bensley, D., Crowe, D. S., Bernhardt, P., Buckner, C., & Allman, A. L. (2010). Teaching and Assessing Critical Thinking Skills for Argument Analysis in Psychology. *Teaching Of Psychology*, *37*(2), 91-96.

The Critical Thinking Co. Staff. "What Is Critical Thinking?" *The Critical Thinking Co*. The Critical Thinking Co, 2 Sept. 2005. Web. 11 Nov. 2013.

"Defining Critical Thinking." *Defining Critical Thinking*. Foundation for Critical Thinking, n.d. Web. 11 Nov. 2013.

"Critical Thinking: Where to Begin." *Criticalthinking.org*. The Foundation for Critical Thinking, Web. 12 May 2013.

"Determine the Root Cause: 5 Whys." *Isixsigma.com*. ISixSigma, n.d. Web. 12 May 2013. <http://www.isixsigma.com/tools-templates/cause-effect/determine-root-cause-5-whys/>.

Eli Pariser: Beware Online "Filter Bubbles" [Video file]. (2011). Retrieved from http://www.ted.com/talks/eli_pariser_beware_online_filter_bubbles

Ennis, R. H. (1996). *Critical thinking*. Upper Saddle River, NJ: Prentice Hall.

Ennis, Robert H. "Definition of Critical Thinking." *CriticalThinking.net*. 26 Nov. 2010. Web. 12 May 2013.

Ennis, Robert H., PhD. "Is Critical Thinking Culturally Biased?" *Teaching Philosophy* 21.1 (1998): 15-33. *Illinois.edu*. University of Illinois. Web. 8 May 2013. <http://faculty.education.illinois.edu/rhennis/documents/EnnisCTCultBiased.pdf>.

Facione, P. A. (1990). The Delphi report. *Committee on pre-college philosophy. American Philosophical Association*.

Grant, G. E. (1988). *Teaching critical thinking*. New York: Praeger.

Halpern, Diane F. "Teaching Critical Thinking for Transfer Across Domains." *American Psychologist* 53.4 (1998): 449-55. *Google Scholar*. Web. 18 Mar. 2013. <http://projects.ict.usc.edu/itw//vtt/HalpernAmPsy98CritThink.pdf>.

Paul, Richard, Dr., and Linda Elder, Dr. *The Miniature Guide to Critical Thinking Concepts and Tools*. Special ed: Foundation for Critical Thinking, 2007. *D.umn.edu*. University of Minnesota Duluth. Web. 8 May 2013. <http://www.d.umn.edu/~jetterso/documents/CriticalThinking.pdf>.
The Truth About Martin Luther King. (n.d.). Retrieved from http://www.martinlutherking.org/

Way, T. (n.d.). *DHMO Facts*. Retrieved from http://www.dhmo.org/facts.html