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Full-Cycle Assessment of Critical Thinking in an Ethics and Science Course

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Keywords

Critical thinking, Assessment, Rubric, Writing

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Abstract

Enhancing critical thinking skills for undergraduate students is important across the curriculum and between disciplines. We report on a method of improving critical thinking skills, which was studied through an Ethics and Science First-Year Seminar course. We used full cycle assessment over a three-year period to assess students' development and to modify the course teaching and assignments with the goal of increasing student development of critical thinking skills. Data were obtained from student writing throughout the semester during each offering. Modest, but significant, overall gains of ~ 0.7 on a 4 point scale are reported between early and midterm assignments in the course using a seven trait assessment rubric. Key factors that contribute to the increase in critical thinking skills are identified including peer review, scaffolded assignments, and the use of a grading rubric for each assignment.

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Introduction

Understanding how students learn and the ways in which different pedagogical techniques affect that experience is the basis for promoting a rich and fruitful learning environment that serves everyone - individual students, faculty, educational institutions, and society at large - as these students graduate and move into the workforce. The premise that critical thinking skills are foundational to learning across many disciplines and that undergraduate curriculum should advance these skills for students is broadly supported by faculty across the nation. Improvement of critical thinking skills is in the national spotlight as institutions respond both to faculty concerns that students are failing to exhibit high level reasoning skills and to external pressures to document and assess student learning (American Council on Education 2004; Pusateri & Hurd 2006; U.S. Department of Education 2006).

In this paper, we report on a full-cycle assessment of critical thinking in three years of teaching an ethics and science first-year seminar course. First we reflect on the definitions of critical thinking, and then we describe our methodology and assessment efforts. This is followed by a brief description of the ethics and science course including the pedagogy and the specific assignments that are assessed for critical thinking skills with a carefully developed rubric. Finally, we report our results over three years which allow us to identify key elements which improve students' critical thinking.

Improving Critical Thinking During College

Research on critical thinking is based on a variety of assessment methods, as well as a variety of definitions of the term critical thinking. We find the following two definitions particularly useful.

The Foundation for Critical Thinking uses the following description:

Critical thinking is, in short, self-directed, self-disciplined, self-monitored, and self-corrective thinking. It requires rigorous standards of excellence and mindful command of their use. It entails effective communication and problem-solving abilities and a commitment to overcome our native egocentrism and sociocentrism. (Paul & Elder 2004, pg. 1)

In her 1988 book on critical thinking, Joanne Kurfiss proposed the following:

Critical thinking is a rational response to questions that cannot be answered definitively and for which all the relevant knowledge may not be available. It is defined here as an investigation whose purpose is to explore a situation, phenomenon, question or problem to arrive at a hypothesis or conclusion about it that integrates all available information and that can therefore be convincingly justified. In critical thinking, all assumptions are open to question, divergent views are aggressively sought, and the inquiry is not biased in favor of a particular outcome. (Kurfiss 1988, pg. 2)

Both definitions of critical thinking focus on the ability to study an issue using problem solving techniques, which include assembling relevant data or information, being open to different points of view, and then forming conclusions based upon the evidence, rather than personal opinions.

Just as there are a variety of definitions of critical thinking, assessment methodologies of student development of these skills range from student self-reporting of their abilities, to nationally available tests, to individual assessment rubrics developed by researchers. For example, several studies used students' self-report of their own critical thinking abilities to track improvements in student learning (e.g., Broadbear 2003, Tsui 1999). One concern with these studies is that students usually over-estimate their own ability to use skills they have recently been taught (Dunning et. al. 2004). Some studies use a subset of the Collegiate Assessment of Academic Proficiency (CAAP), a test developed by ACT to assess general education programs (<http://www.act.org/caap>, Pusateri & Hurd 2006). Other individual researchers (e.g. Bissel & Lemons 2005, Zeller & Tsaparlis 1997) have based their assessment of critical thinking on Bloom's *Taxonomy of Educational Objectives* (Bloom 1984), in which questions of application, analysis, synthesis, and evaluation are ranked higher than questions of knowledge or comprehension. King and Kitchner (1994) have created a reflective judgment model of critical thinking, which defines seven levels of judgment. This is a developmental model; students need to reach the first level before they can reach the second, and so on. As students move through the levels, they become more able to identify different perspectives, and they learn to choose among them. These critical thinking skills can be applied to problem solving or to the development of an argument.

Various aspects of attending college help students to increase their critical thinking ability (Astin 1993; McMillan 1987, Pascarella 1989, Terenzini et. al. 1995), but the reported

increases are modest. Most studies show that no individual experience or mode of instruction was crucial on its own, but that the aggregate of both in-class and out-of-class experiences changed students over a period of a year or more. In fact, effects are quite small, even when they are statistically significant. For example, Terenzini, et. al. found that the effects of college are smaller than the contributions of pre-college experiences, as measured by a pretest of critical thinking (Terenzini et. al. 1995). Some aspects of instruction do seem to help students develop their critical thinking. For example, giving students problems for which no single answer is correct, having students revise writing assignments, giving students the criteria for assessing critical thinking, and the use of scaffolded assignments have all been found to be helpful (Broadbear 2003, Butler, Stonewater & Kinney 2005, Astin 1993, Van Gelder 2005, Bean 2001, Lynch & Wolcott 2001).

Several recent studies have done more targeted assessments of undergraduate students' skills and have found that improvements in student abilities seem to be less than faculty might expect from their own anecdotal experiences. King and Kitchner (1994) found that students in their first year of college have a mean reflexive judgment score of 3.63 (on the scale of 1 to 7), and students in their senior year had a slightly improved average score of 3.99 (King & Kitchner 1994, p. 161). Students with a score of 3 will try to find the "correct answer" to unstructured problems, ignoring contradictory evidence as they try to make things simpler. Students with a score of 4 can accept uncertainty, but have trouble distinguishing between opinion and evidence.

Wolcott and associates have built on this work, adapting King and Kitchner's seven levels into five performance levels, labeled 0-4 (Wolcott & Gray 2003). At the lowest levels, students do not see their own biases. As students develop, they learn to see other people's point of view and move beyond the "perpetual analyzer" stage to the stage where they can use arguments to make practical decisions. Wolcott has found that 50% of college students in their first year are unaware of any assumptions they or others are making and insist that there be one correct answer to even the most open-ended questions (level 0). By the time students are seniors, a majority of them have moved from level 0 to level 1, where they can acknowledge other viewpoints, but usually only perceive evidence that supports their own opinion (Wolcott & Gray 2003). Again, this is a small improvement; very few students reach the highest levels of critical thinking in college.

In order to formally measure critical thinking skills, The Center for Teaching, Learning, and Technology, the General Education Program and the Writing Program at Washington State University developed a critical thinking rubric to be used on written work (<http://wsuctproject.wsu.edu>). The rubric, developed in 1996, has the following seven traits: problem identification, establishing a position, consideration of other perspectives, consideration of context, providing evidence, examining assumptions, and drawing conclusions. (Brown 2004) Each of these traits was assessed on a scale of 1 to 6. Professors at Washington State University have found that using the rubric throughout a course helps students' critical thinking skills. In a 400-level course without the rubric, papers were rated an average of 1.9, while in the same course with the rubric the papers were rated an average of 3.5, a significant difference (Conlon & Kelly-Riley 2004, Kelly-Riley 2003).

In addition, when faculty members at Washington State University assessed writing assignments, they found that many of them ask for a high level of critical thinking, and that students exhibited better critical thinking in their work when the faculty specifically asked for it (Brown 2004).

As we have seen above, several pedagogical techniques have been identified as methods for increasing student abilities in the area of critical thinking. In addition, a number of assessment tools have been developed to investigate the nature of student performance, each of which have common themes but different rating scales. The research on student development of critical thinking skills concludes that it is difficult to improve students' critical thinking skills, and thus modest gains are noteworthy.

Settings and Subjects

In this paper we present a full-cycle assessment of a seminar for first-year students at Miami University, an Ethics and Science course. In full-cycle assessment, the results of assessment are used to redesign assignments, which are then re-assessed the next time the course is taught. This has been found to be an effective method for course redesign (Butler, Stonewater, & Kinney 2005). We have used this iterative full-cycle assessment framework to address the question: "How do we improve students' critical thinking?"

Miami University First-Year Seminar Classes

Miami University began offering First-Year Seminar Classes in Fall 2004. The goal of these courses was not only to raise the intellectual climate for first-year students, but also to provide them with a low population, seminar-style course that fostered student-student interaction, student-teacher interaction, and student responsibility for learning. The courses have an enrollment cap of 20, and 9 to 14 are offered each semester. Faculty members were asked to submit proposals for these new courses and course topics were selected from these submissions. The seminars run 2-3 times, and then are replaced with new courses. The seminar discussed here is the Ethics and Science First-Year Seminar Course taught by Yarrison-Rice, which was offered in Fall 2004, Fall 2005, and finally in Spring 2007. Enriching first-year students' experiences is particularly important in terms of critical thinking, as Wolcott has reported that ~50% of entering college students are at the lowest development level (called "confused fact-finder" on Wolcott's) in their critical thinking skills as demonstrated through their writing (Wolcott & Gray 2003).

General Structure

The Ethics and Science Course begins with simple questions on the nature of science, and then considers topics such as scientific misconduct, ownership of data and intellectual property, human and animal experimentation, public health, conflicts of interest, and bias in research. A series of real-world current news articles, case studies, and short vignettes are used to explore these ideas and the ethical issues surrounding them. Specific topics are explored in the following manner. Students are given news articles or sections of the textbook (Elliot & Stern 1997) to read on a particular topic. An initial discussion is held (in some cases an expert is invited to come to the class and present information from that area), and case studies are used to elicit student opinion. Students, working in groups of four, then embark on fact-finding missions, and a debate or discussion on issues is held with different groups presenting different sides of the question and leading the discussion. The case study analysis is organized as follows. Students analyze case studies and news articles to learn about the details involved and to envision the different directions in which issues might further develop. They are asked to identify the following points in each situation that is considered.

- What are the facts of the case?
- What are the issues brought out in the study?

- Who is affected by the problem (may or may not be persons directly mentioned in stories)? What are their perspectives and values?
- What professional knowledge would I need to know in order to make an informed decision about this topic?
- What are possible actions that could be taken, and which are most important (prioritize)? Consider both short term and long-term actions.
- What are the possible consequences of such actions? Consider ethical implications, practical constraints, and identify both positive and negative aspects of the course of action.

Written assignments range from analyzing specific scenarios and taking a stance to defend to writing reflection papers on more global questions after a topic has been studied.

This research project on critical thinking was born out of dissatisfaction with the students' critical analysis as demonstrated in their early written assignments in the first offering of the course. We realized that the case study oriented curriculum would allow us to track how students approach critical thinking. The analysis of case studies requires students to use the seven critical thinking traits of our own Washington State University-based rubric, and we thought a student's well-written assignment should also contain evidence of her/his use of these skills. These assessments would provide information that could be used to improve the second offering of the course.

Assignments in Fall 2004 consisted primarily of two types of assignments: 1) reading and analyzing case studies using the "talking points" (bulleted above), and 2) a series of open-ended "reflection" questions for students to use to articulate a response to the issues we were considering in a given part of the course. The goal of the reflection questions was to lead students to synthesize the case study with their own personal values and ideas, as well as other people's perspectives, and to come to conclusions which they could then support with evidence from the cases. The three assignments described below were used for the critical thinking assessment.

The first assignment was one in which students were asked to analyze real-life case studies of scientific misconduct investigations across the country. Students were broken into groups. Each group was responsible for one case study. Each person in the group was asked to take one additional question produced by the group and research it further. The new information on the case would add more depth of understanding of particular issues or provide a broader database from which to discuss and examine the issues of the scientific misconduct.

The second assignment we assessed, the midterm, asked students to select their own individual case study and fully analyze it. Students did their own research using what they had learned earlier about online academic search engines in a session with a science librarian. Students were to find their own case studies or other science news stories which had a strong ethical component to them. Then they analyzed the cases using the talking points and wrote their midterm papers based upon these cases/science-based ethical issues.

In the final assignment, the students are asked to address the following question: What ethical science issue do you feel strongly enough about to proactively work towards resolving? Students were asked to use different case studies from throughout the semester

to provide examples and to support their stances. These three assignments were quite open-ended and, in retrospect, seemed to leave first-year students somewhat unsure as to how to approach them, even by semester's end. Other assignments throughout the semester focused on more specific case studies and vignettes from our readings about particular topics, but these assignments also contained open-ended questions for students to reflect on the ideas presented in a very broad way. The premise was that students would feel freer to write about topics in their own way. *Students were not presented with any information specific to critical thinking skills during the first offering of the course, but, as described later, they were introduced to critical thinking in subsequent course offerings.*

Methods

The assessment of critical thinking in the papers written by the Ethics in Science students was carried out by Miami University Assessment Fellows. This group of a dozen faculty members including Taylor, representing a wide spectrum of academic disciplines, was constituted in the fall of 2003 for the purpose of enhancing the teaching and learning of critical thinking skills at Miami. Enhancing critical thinking is one of the four goals of Miami's general education curriculum, yet there has been little consensus on either the meaning of critical thinking or how to measure it. The goals of the Assessment Fellows were to create a definition of critical thinking that could be agreed upon by most disciplines, to develop means of assessing critical thinking, and to assist faculty in carrying out assessment projects. After yearlong discussions on assessing critical thinking, the Fellows agreed to adapt the Washington State University rubric for measuring seven primary traits of critical thinking. Because the research on critical thinking states that undergraduate students are not likely to develop through the full range of stages found in the Washington State rubric, the Miami University rubric was condensed to four stages of development. The rubric as modified by Taylor for use by the Assessment Fellows may be found in Appendix A (Blue, Taylor, & Yarrison-Rice 2006). The original Washington State Rubric only had descriptions for the highest and lowest points on the scale. Because the Fellows found this difficult to use, Taylor wrote descriptions for each of the intermediate stages, so that descriptions were complete for all four stages of each of the seven traits.

The seven primary traits identified for assessment were

1. Identifies and summarizes the problem/question at issue
2. Identifies and presents the student's own perspective and position as it is important to the analysis of the issue
3. Identifies and considers other salient perspectives and positions that are important to the analysis of the issue
4. Identifies and assesses the key assumptions
5. Identifies and assesses the quality of the supporting data/evidence and provides additional data/evidence related to the issue
6. Identifies and considers the influence of context on the issue
7. Identifies and assesses conclusions, implications, and consequences

The rubric describes four levels of performance for each of these traits: scant, minimally developed, moderately developed, and substantially developed, each of which is given a numerical rank, from 1 for "scant" through 4 for "substantially developed". The decision was made to assess only the first paper written, the midterm paper, and the final paper, because a high quality response on each of these assignments would require evidence of all seven critical thinking traits.

Prior to assessing the Ethics and Science papers, the Assessment Fellows participated in several norming sessions lead by members of the English department, who were experienced in using rubrics to assess student writing, to make sure that all were interpreting the criteria and the rubric levels in the same way. Since then, the Fellows have carried out a number of assessment projects for the university. Inter-rater reliability has been good; typically the fellows' ratings differ by no more than one level 90% of the time.

In accordance with our approved Institutional Review Board protocol, students in the class were informed of the research project and given the option of not having their work included. All students who did not opt-out signed an informed consent form. Thirteen out of twenty-one students agreed to participate the first year. (In Year 2, 13 of 19 students participated, and work from 11 of 20 students was assessed in the third year) Student names were removed from the papers and a number was assigned to each. These numbers were randomized so that it would not be obvious to the readers which papers were written early in the semester and which were from late in the semester. Records were maintained so that the researchers can tell which sets of three papers were written by the same student, but all data associating that set with a particular student was destroyed. Copies of all the papers are archived in the University Assessment Office. Each student paper was read and assessed by two Assessment Fellows using the modified Washington State rubric. Distribution of the papers was randomized so that each rater had some papers from each assignment, and so that it was unlikely a rater would have two papers from the same student. Averages were calculated for each trait. A frequency analysis of the number of times each of the four categories were used for each trait was also performed, which provides another lens through which to look at the data.

We next present the results of the assessment of critical thinking development in the Ethics and Science class during each of the three years of this study. Using our modified Washington State rubric, papers were scored on the seven critical thinking traits on a scale of 1 to 4. Averages of each of the seven traits for all student scores were calculated, as were the changes in scores throughout the semester and between each different year of the course offering. In addition, a frequency analysis of the number of times a particular trait was scored with a particular score is provided in a series of tables. These results are reported in separate sections for each year the course was offered. Each year's results section is followed by a description of the modifications we made to the course after the assessments were conducted and analyzed. Lastly, a discussion of the conclusions we draw from the full-cycle assessment is provided.

Results - Year 1

The averages reported here are the average of all Fellows' ratings of all student papers on each trait (Table 1). The ratings on the early papers show students averaged between scant (1) and minimally developed (2) in all categories. Students were rated highest in their ability to identify the problem (average 1.8) and next highest at identifying their own perspective (average 1.5). The other critical thinking tasks had averages between 1.2 – 1.3.

However, even the highest score of 1.8 reflects that the students' ability to identify the problem is at best "minimally developed."

Table 1: Average Scores, Year 1 (Average of all Fellows' ratings for each trait)

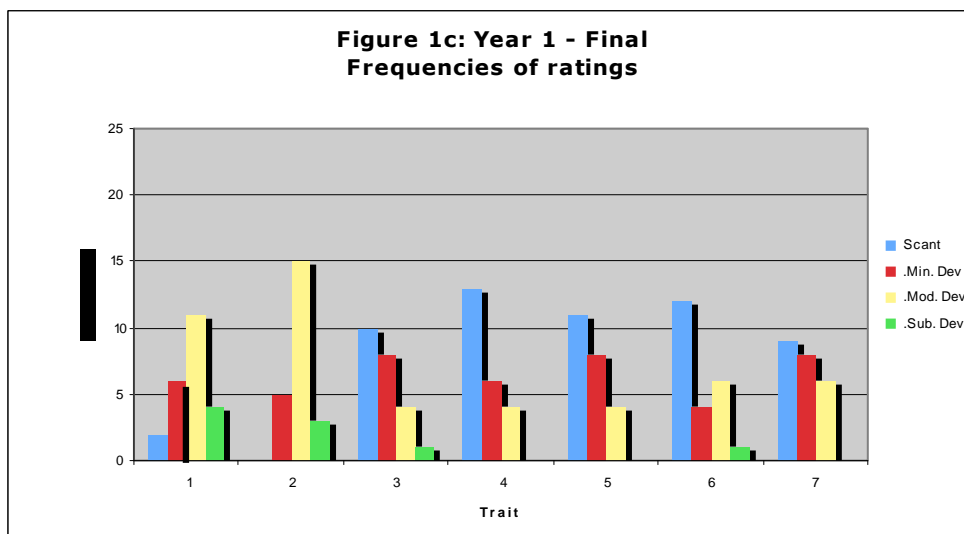
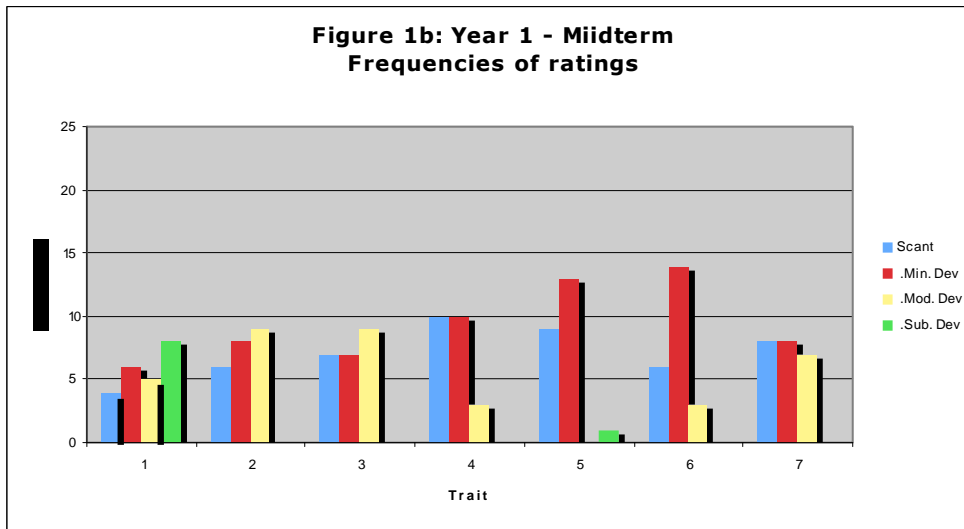
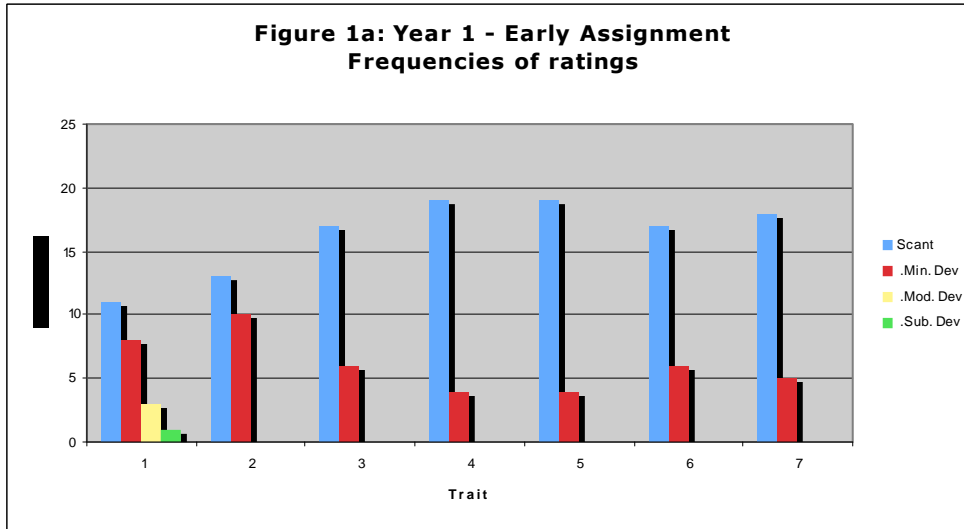
	Early Assignment	Midterm	Final
Identify Problem	1.8	2.8	2.7
Student's Own Perspective	1.5	2.1	2.9
Other Perspectives	1.3	2.1	1.8
Assumptions	1.2	1.7	1.6
Using Evidence	1.2	1.7	1.7
Contexts	1.3	1.9	1.8
Conclusions	1.3	1.9	1.9

The students demonstrated considerable improvement between the early assignment and the midterm paper. Students were still best at identifying the problem (average 2.8, up from 1.8), and their next highest average ratings were in identifying both their own perspective and other perspectives (average 2.1, up from 1.5 and 1.3 respectively). The ratings on the other critical thinking tasks showed gains of 0.5 -0.6 from the early assignment to the midterm. For the midterm paper, the highest individual ratings approach a score of 3, which means "moderate" evidence. Overall, no improvement was found from the midterm paper to the final paper. Most of the averages stayed within 0.1 of what they had been at the midterm, with two exceptions. Students' average ability to identify their own perspective increased significantly, by 0.8 (from 2.1 to 2.9), while their average ability to identify other perspectives decreased from 2.1 to 1.8.

One reason for the changes in averages of these two traits between the midterm and the final paper might be the change in the nature of the assignment. The midterm paper was a straightforward *single* case study analysis, while the assignment for the final paper, which asked students to choose an ethical issue they would be willing to work towards changing, may have prompted the students to think about their own perspective more than the perspectives of others. The overall lack of improvement between midterm and final also points to the differences in assignment, as a well-developed response for the final would require students to synthesize information from several case studies (rather than just one) which requires proficiency in higher-order skills than those needed for analyzing a single case study.

Looking at the frequency data provides insight into the question of student improvement. The frequencies of the ratings given to student papers on the first assignment for Year 1 are shown in Figure 1a. These are not averaged; since two readers read each paper, both of those ratings are shown separately on the chart. The increases in individual students' scores are graphically exhibited as one views each trait's frequency distribution in vertical fashion from the early to midterm to final assignments.

The frequency data for the first paper show that only one trait, identifying the problem, had many papers that received a 3 or 4. In fact, the rest of the traits were predominantly scored as 1 (or scant development) with a few papers receiving a 2. The frequency data for the



midterm paper shows a strong shift upwards, as shown in Figure 1b. The Fellows gave far fewer ratings of 1 and far more ratings of 3 on the midterm paper than on the first paper. The rating most often given is no longer a 1, but a 2. The upward trend from the midterm is continued into the final in terms of the frequency distribution. Recall that the *averages* for five of the seven traits were very similar, the exceptions being traits 2 (student perspective which increased by 0.8) and 3 (other perspectives which dropped by 0.3). However from the frequency data, one can see that there are many more ratings of 3 given than there were on the midterm paper and a few traits received scores of 4. One can also see that some students reverted to scores of 1 on some traits. Thus, while the average scores remained about the same, individual scores did not. Again, this may be the result of the nature of the assignment for the final paper. Some students were able to use the open-ended nature of the assignment to showcase their critical thinking skills, while others apparently did not interpret the assignment as requiring anything other than their own perspectives.

Course Modifications for Year 2

The first offering of the course did not focus on the development of critical thinking in terms of instruction. As a result of the assessment for the three different assignments in the first year, the authors decided on several modifications for the second offering of the Ethics and Science course. We decided to openly discuss critical thinking with the students and to make development of such skills a parallel goal for the course. Because even at semester's end in the first course offering students seemed to exhibit mostly lower-level critical thinking skills, we decided that we needed to change the next course offering to include multifaceted approaches to the development of critical thinking including:

- assignments designed specifically to teach the ideas behind critical thinking
- assignments which broke down the critical thinking skills into smaller increments
- assignments which built from the lower level critical thinking skills up to more difficult skills -- or scaffolded assignments
- some assignments interspersed through the semester which brought all the skills together
- use of a grading rubric which outlined the particular critical thinking skills we were targeting in each assignment

We also decided to provide the students with the grading rubric in advance, concurrent with each assignment, so that students could see what was expected. Grading rubrics (to be differentiated from critical thinking assessment rubrics) had not been used in the first offering of the course. We designed the grading rubrics to contain the different aspects of critical thinking and give specific point values for various skills, which varied throughout the semester as students became more sophisticated in their application of critical thinking skills. Students were also given a handout that elaborated on the meanings of each of the seven critical thinking traits providing specific examples related to course materials.

Assignments in Fall 2005 (Year 2) were based on many of the same case studies as the previous year, although some readings changed as the news brought different ethical issues to the forefront. Our research group met several times throughout the semester to select different types of scaffolded assignments that could be given and to work out a grading

rubric. The revised assignments followed the above bulleted guidelines within the curricular needs of the course.

The first writing assignment in the second year focused on the ethics of doctors being paid by investment companies to answer questions about research or the general state of a current medical topic. Students were asked to apply the seven critical thinking traits to this case study in an essay format. The second (midterm) assignment was basically the same as the midterm in the first year. Students were asked to choose their own real-life ethical dilemma and study it using news articles and/or websites with pertinent information on the topic, so that they could analyze the dilemma. The major difference in the assignment was that the grading scheme for the midterm essays was provided in advance.

The assignment for the 2005 final paper was more focused than the previous year's final assignment. Students were asked to write a 4-6 page paper on one question - Should society's perceived need for information ever override individual rights? They were told to use specific case studies and classroom discussions to describe their views and support their opinions. Students had to integrate evidence from several sources rather than concentrating on a single case study. The grading scheme for the final essay is found in Appendix B. The grading rubric for the midterm was similar to that used for the final essay, but with the last few traits weighted less heavily.

Part of our goal with the second year's offering of the seminar was to move students through different assignments, each of which would highlight different critical thinking skills. In addition, as the semester progressed the grading rubrics would then be weighted more heavily toward the more difficult levels, as students mastered the lower level skills. We use the term "scaffolded assignments" to describe this progression, and give more details on some of these assignments below.

For example, early in the semester students were asked to simply identify the main dilemma a case study presented and to describe what the issues were and who was affected by the problem. Then they were asked to present their own perspective on the issue. At every step of the way, students were expected to document their findings with evidence from outside references. Students were then asked to consider other affected parties' positions on an issue. This forced them to think outside their normal comfort zone and to put themselves in other people's places. Students' ability to do this varied significantly from person to person. The use of an in-class formal debate for two topics forced them to consider both sides of different issues and really appealed to the students. In fact, one assignment was key to their development of this ability. They were asked to write a pro-statement and a con-statement about the use of animals in research, and to write them in such a way that a reader could not decide which opinion was actually theirs. Students did surprisingly well at making a strong argument on both sides of the issue.

Results – Year 2

The Assessment Fellows used the same rubric to rate the essays written to fulfill the modified assignments and teaching strategies used in Year 2. Again, only the first paper, midterm, and final paper were used for the critical thinking assessment, because they were comprehensive enough to require the use of all seven primary traits on the critical thinking assessment rubric. The evaluations of student critical thinking from Year 1 and Year 2 were very similar, as presented in Table 2. We see a gain in student learning of critical thinking skills between the early and midterm assignments, and then a plateau to the final assignment. The gain in average scores for Year 2 were highest in the first three traits. In

trait #1, identifying the problem the gain was around 1 (from an average score of 1.5 to 2.5) which was the same gain seen in Year 1, with the students' ability to relay their own perspective gaining 0.7 (from 1.8 to 2.5), and for identifying other people's perspectives students gained 0.6 (from 1.5 to 2.1). In the other four traits, student gains varied between 0.3 and 0.5 in Year 2. In the final paper, students' scores either stayed the same or dropped slightly across all traits (which is why they are not shown on this table). This contrasts to the final paper in Year 1 where the students' own perspective showed a large gain.

Table 2: Average Scores, Years 1 and 2 (Average of all Fellows' ratings for each trait)

	Early Assignment Year 1	Early Assignment Year 2	Midterm Assignment Year 1	Midterm Assignment Year 2
Identify Problem	1.8	1.5	2.8	2.5
Student's Own Perspective	1.5	1.8	2.1	2.5
Other perspectives	1.3	1.5	2.1	2.1
Assumptions	1.2	1.2	1.7	1.7
Using Evidence	1.2	1.4	1.7	1.8
Contexts	1.3	1.5	1.9	1.8
Conclusions	1.3	1.5	1.9	1.9

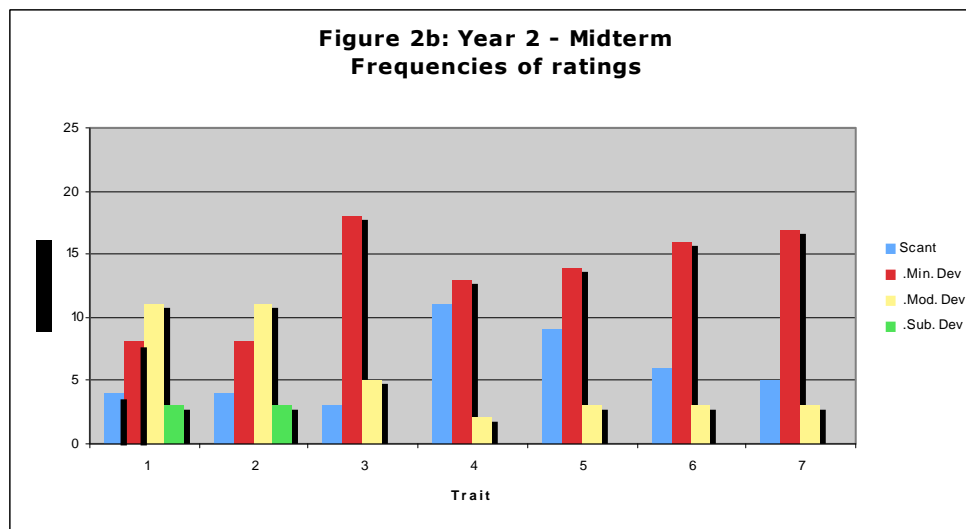
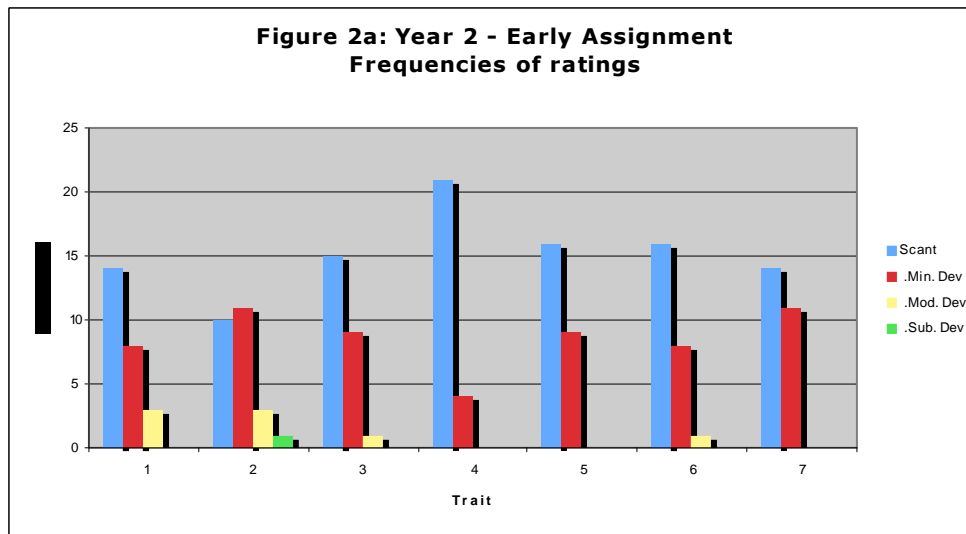
The final paper in Year 2 was required integration of several case studies to answer the question in a defined topic, so while student' critical thinking skills may be improving for single topic analysis, when asked to address a broader question drawing evidence from several cases, students critical thinking scores were rather level. The frequency data for this paper show that individual scores increased over Year 1 with more ratings of 2 and 3. (See Figure 2.), However, the numerical averages were not much different between years indicating that individual student learners exhibit some higher gain in Year 2 than 1, but that the class as a whole experienced a similar overall gain. An individual student's increase in performance might be attributed to our clarifying the assignments and using scaffolding assignments. The results of the frequency distribution comparing the midterm assignment with the final assignment are very similar to Year 1 results with more spread seen in the individual scores.

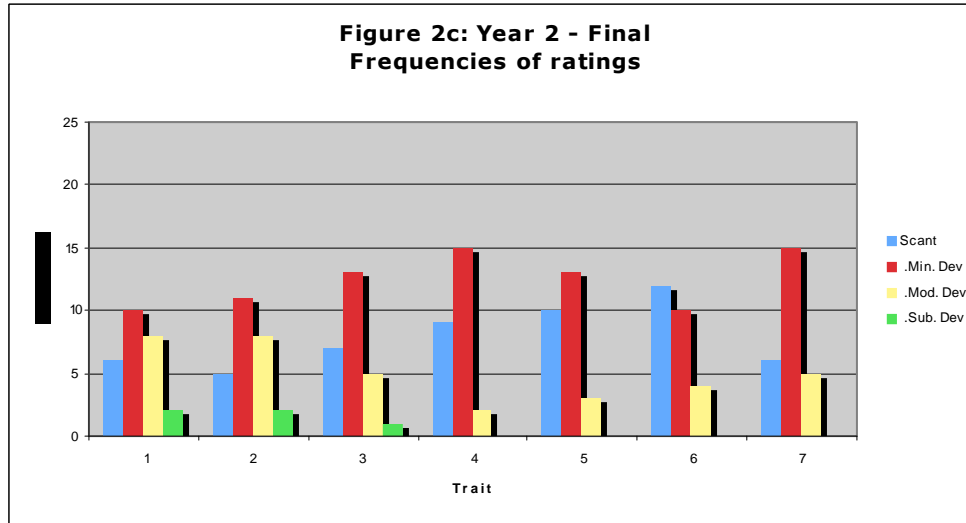
Course Modifications for Year 3

Before the third year this course was offered, we reviewed the course materials and assignments in light of the results of our critical thinking assessment. Because in the second year rubrics assisted both the faculty member and the students as they considered, wrote, and then graded assignments, we wanted to continue their use in the course. However, since student writing seemed to be more stilted when the rubrics were used (often assignments became as a seeming check-list for the rubrics), we decided to provide a less detailed rubric which identified the major requirements for an assignment, but did not order them particularly or assign point values in advance. Our thesis was that the positive effect of seeing the different critical thinking requirements would remind students about how to approach a particular assignment without losing their individuality. Several more scaffolded assignments were designed for the course as well.

Another conclusion we drew from the first two times the course was run was that the use of open topics, where students choose topics themselves, for midterms and finals seemed to negatively affect students' critical thinking and analysis of case studies. In particular,

students tended to pick topics for which they had strong opinions, and this had the effect of clouding their critical thinking in terms of being able to analyze dispassionately other points of view and to find good evidence to support opposing ideas. Thus, we decided to limit students' topic selection and provided a series of 5-7 topics for students to choose from for their midterms and finals in order to let them analyze and write more balanced papers. In





order to have uniformity from year two to three, we kept the same final exam question for the students to address with the small modification that students could consider the rights of small groups of people versus larger populations or national/international good, rather than just the rights of the individual, if their particular topic merited such an approach.

In the third year, students were also required to have a peer review of their midterm and final papers, and were given the opportunity to turn in an outline for instructor review before their final papers were due. In previous years, peer reviews were suggested, but not required, for all the papers.

Results – Year 3

The third time the Ethics and Science course was offered was in the spring of 2007. Students in this seminar thus had a full semester of undergraduate education before joining this course; in contrast, the first two times the course was conducted were in the fall semester when students first came to the university. We were interested in how this semester's worth of preparation and experience would affect the critical thinking baseline of our students, and indeed found that students began the second semester of college at a higher critical thinking level than in the first semester. This is evidenced in the averages of the first assignment of the course. (See Table 3.) In Year 3, the average assignment score was higher by approximately 0.4 (calculated from the difference between Year 3 and the average of Year 1 and Year 2 scores together). Thus, it is more instructive to look at changes in average scores for the student gains during the semester, rather than the absolute scores they received. (See Table 4.)

In the first assignment of Year 3, students had their highest averages for the first three traits: identifying the problem (2.0), describing their own perspective (2.2) and recognizing other people's perspective (1.9). The first two traits were high for all three years in the first paper. The gains from the early assignment to the midterm are strong in three areas: in identifying the problem (0.8 gain), in using evidence (1.0 gain), and in context (where a 0.8 gain was observed). The first gain was also seen in Years 1 and 2; however, the gain in using evidence to support conclusions and discussions and identifying contexts was much stronger in Year 3 than previous years (Year 1 changes were 0.5 and 0.6 and Year 2

changes were 0.4 and 0.3 respectively). The other traits had gains of 0.6 to 0.7 for Year 3. Once again with the midterm to final assignment, the Year 3 averages either did not change or were slightly lower.

Table 3: Average Scores, Year 3 (Average of all Fellows' ratings for each trait)

	Early Assignment	Midterm	Final
Identify Problem	2.0	2.8	2.5
Student's Own Perspective	2.2	2.9	2.6
Other Perspectives	1.9	2.5	2.2
Assumptions	1.5	2.1	2.2
Using Evidence	1.5	2.5	2.2
Contexts	1.6	2.4	2.0
Conclusions	1.8	2.5	2.2

Table 4: Differences Between Averages on Midterm and Early Assignments
(Average for each trait on midterm – average for each trait on early assignment)

	Year 1	Year 2	Year 3
Identify Problem	1.0	1.0	0.8
Student's Own Perspective	0.6	0.7	0.6
Other Perspectives	0.8	0.6	0.6
Assumptions	0.5	0.5	0.6
Using Evidence	0.5	0.4	1.0
Contexts	0.6	0.3	0.8
Conclusions	0.6	0.4	0.6

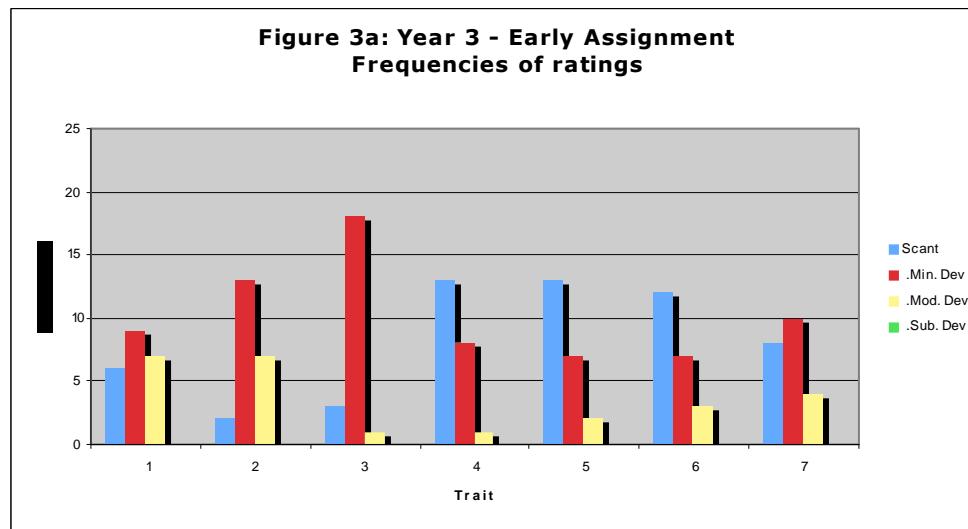
The frequency distributions for Year 3 are shown in Figure 3 for the three assignments. The distributions are quite striking with a strong shift toward higher scores for individual students. Trait 1 (identifying the problem) and Trait 2 (student's own perspective) show many scores of 3 and some of 4 on the midterm assignment, with a drop in development shown in the final paper, which has a more even distribution across scores. The last 5 traits have strong gains from the early assignment to midterm and then also show that several individual students shift up again (to scores of 4 or substantially developed), while several individual students drop down in the last assignment. In the areas of other perspectives and use of evidence the final assignment students generally shift downward in their scores. However, the scores of 4 represent good gains for the individual students as they move through the course. In Years 1 and 2, very few students demonstrated substantial development of critical thinking skills and only in 3 or 4 of the 7 traits. *Year 3 data have some individuals with substantial development of critical thinking skills across all 7 traits.*

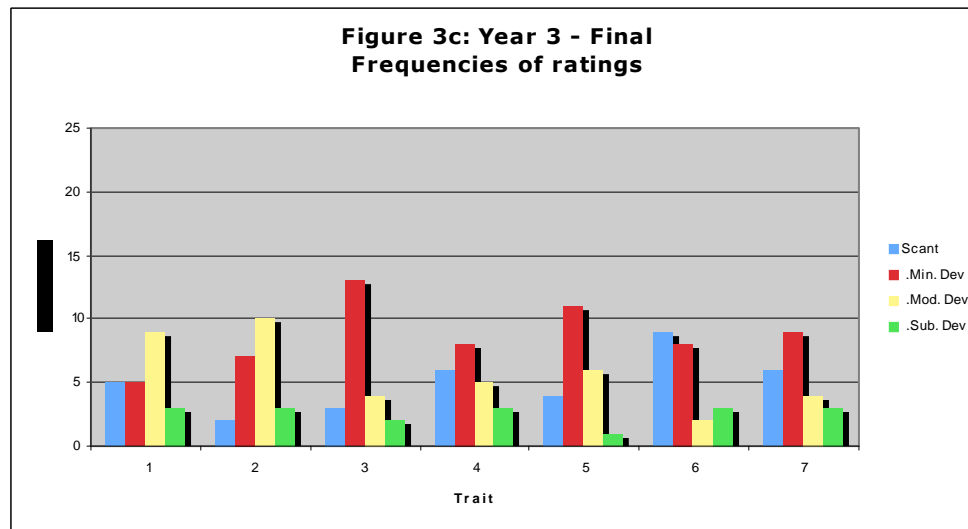
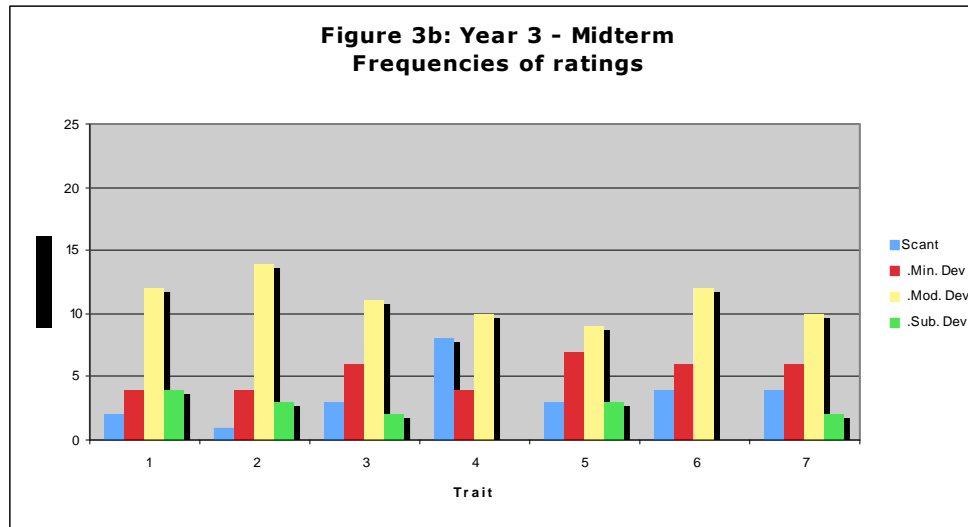
Discussion

We consider the results from all three years collectively in order to draw conclusions about pedagogical techniques that are effective in advancing students' critical thinking skills. In this study, we have seen a significant improvement in students' critical thinking from the early to the midterm assignments. Even in Year 3, where students began with higher scores on their first papers, improvements were seen at midterm. In the first year we attribute that gain to the fact that the early paper was rewritten after feedback from the instructor and peers. In the second year, we attribute the gain to providing the students with rubrics that

helped them apply critical thinking skills to a particular assignment, some use of peer review, and scaffolded assignments targeting specific critical thinking skills such as identifying contexts and assumptions. In the third year, we used the modifications from Year 2 with some additions like slightly modified assignments and rubrics (detailed above); in addition peer reviews were required and students were encouraged to outline their papers before writing first drafts. More specific discussions were held in Year 3 on how critical thinking assisted in analyzing ethical issues and this was reflected in the larger overall gains between the early and midterm assignments in Year 3 particularly with Traits 5 and 6.

In Years 2 and 3, the instructor found the rubrics made the papers easier to grade, made the grading less subjective and, therefore, made the grades easier to explain to the students. At the end of the second year, a brief survey was administered to the students to determine their perceptions of the usefulness of the rubrics. Students were given four positively worded statements related to the rubrics and were asked to respond on a six-point scale from strongly agree (1) to strongly disagree (6).





The results of the survey are shown in Table 5. Clearly, the students found the rubrics helpful. Students strongly agreed with the usefulness of the rubric in writing (1.12 out of 6) and organizing their papers (1.24 out of 6). Standard deviations for these two questions were 0.33 and 0.44 indicating strong agreement among students. Students only somewhat agreed that the rubrics assisted them with bringing critical thinking into their papers (2.35 out of 6) with a high standard deviation (1.37). We believe the difference between the student responses on the questions about general usefulness (Q1 & Q2) and usefulness for incorporating critical thinking into their writing (Q4) results from a lack of understanding of what critical thinking means. Interestingly, this misunderstanding persists even after a semester of instruction aimed specifically at improving critical thinking skills. Students were surveyed orally about the use of rubrics after the third year and they responded positively again about their usefulness in paper writing. The student consensus in both years was that rubrics should continue to be used in future offerings of the course.

Table 5: Student Evaluation of the Rubric, Year 2

	(1) Strongly Agree to (6) Strongly Disagree
1. Having a rubric before I wrote papers was useful	1.12 ± 0.33
2. Having a rubric before I wrote papers helped me organize my writing	1.24 ± 0.44
3. Having a rubric helped me understand my grade	1.88 ± 1.27
4. Rubrics helped me incorporate critical thinking into my writing	2.35 ± 1.37

From Year 1 to Year 2, no significant difference between the midterm critical thinking scores was seen. This points to the difficulties in affecting changes in critical thinking as discussed in the Introduction. However, when comparing the reported scores from Years 1 and 2 for each trait with the scores from Year 3, we see improvements in two traits in the midterm and two in the final papers. And frequency data shows that some students experienced a significant improvement over the semester, as scores of 4 were observed more frequently in the final paper in all seven traits for the Year 3 data compared to Years 1 and 2 where scores of 4 were seen in only four and three traits respectively.

In all three years, the average critical thinking scores did not improve from the midterm to the final. The research of King and Kitchner (1994), Terenzini et. al. (1995), and Wolcott and Gray (2003) found only small changes in students' critical thinking skills over their entire college career, and so in our case the plateauing of student scores could be due to having reached the maximum amount of change that is possible to make in a time period as short as a semester. In addition, the final exam required a more global application of critical thinking skills than the midterm, as students had to integrate a series of case studies together to answer the final exam question; thus, the final assignment was more demanding than the midterm. This increased expectation in the complexity of the assignment may have masked the students' gains in critical thinking ability.

Conclusions

In conclusion, we find that an Ethics and Science seminar provides a good platform for studying students' development of critical thinking skills, as the course uses case studies, and thus provides a wide variety of issues for students to analyze using these skills. We have observed that students have a significant increase in their ability to identify the problem, and provide their own perspective over the first half of the semester in all three years of this study. Changes in students' critical thinking exhibited increases for all seven traits from the first assignment to the midterm of ~0.7 on a full scale of 4, with the particular traits of using evidence as support and understanding contexts showing larger gains in the third year. The students maintained, or increased, their critical thinking scores through the end of the semester as evidenced by the average scores of the final paper staying nearly the same and the larger number of students with scores of 4 (highest rating, "substantially developed" trait or skill) in the final assignment. This improvement in the frequency data was particularly noteworthy in the third offering of the course.

The results from the three offerings of the Ethics and Science seminar are encouraging. Students are indeed developing their critical thinking skills over the course of the semester. A review of other studies indicates that the magnitude of improvement we record, while modest numerically, is significant. For instance, King and Kitchner found that students typically move one point on their five-point scale or ~20% between first year and the end of college (King & Kitchner 1994). Here we observe a comparable increase of 16% over a

semester for first-year students, with a number of students moving upward to critical thinking score of 4 across the seven different traits in their final papers in the Year 3 offering of the course.

Factors that most likely contributed to these gains include:

- carrying out discussions specifically on the analysis of case studies including specific aspects of critical thinking
- using scaffolded assignments which focused on particular critical thinking traits in order of complexity
- providing students with a rubric for assignments
- providing students with a short list of possible cases and issues for major papers, rather than leaving the choices for students fully open
- having students peer review rough drafts of major assignments and having them rewrite the drafts for final submission

Finally, we conclude that enhancing students' critical thinking skills requires the instructor to use a series of pedagogical techniques: from the choice of ethical issues for students to analyze, to careful crafting of assignments and classroom activities, to the use of peer reviews and rubrics. No single approach guarantees success. However, when an instructor incorporates these ideas together into a course, we find that it is possible to promote the development of critical thinking skills and that students demonstrate a significant gain in their abilities. Thus, the use of full-cycle assessment in a course can provide faculty with the data necessary for identifying which teaching methods are most effective and for coming to a better understanding of student development of critical thinking skills.

Acknowledgements

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Appendix A
Miami University Adaptation of the Washington State University Critical Thinking Rubric

(1- scant)	(2 - minimal)	(3 - Moderate)	(4 - Substantial)
1) Identifies and summarizes the problem/question at issue (and/or the source's position).			
<i>Scant</i>	<i>Minimally Developed</i>	<i>Moderately Developed</i>	<i>Substantially Developed</i>
-Does not identify and summarize the problem, is confused or identifies a different and inappropriate problem. -Does not identify or is confused by the issue, or represents the issue inaccurately.	-Identifies the main problem or question but does not recognize subsidiary or implicit aspects of the problem. -Demonstrates a basic understanding of the assignment.	-Identifies the main problem or question and some but not all of the complexities or nuances associated with the problem. -Demonstrates a good understanding of the assignment and related course material.	-Identifies the main problem and subsidiary, embedded, or implicit aspects of the problem, and identifies them clearly, addressing their relationships to each other. -Identifies not only the basics of the issue, but recognizes nuances of the issue.
2) Identifies and presents the STUDENT'S OWN perspective and position as it is important to the analysis of the issue			
<i>Scant</i>	<i>Minimally Developed</i>	<i>Moderately Developed</i>	<i>Substantially Developed</i>
-Addresses a single source or view of the argument and fails to clarify the established or presented position relative to one's own. Fails to establish other critical distinctions. -Fails to acknowledge the existence of valid counter arguments.	-Identifies one's own position on the issue relative to other positions, but does not provide supporting evidence for the position. -Fails to acknowledge the possible validity of other positions	-Identifies, appropriately, one's own position on the issue, drawing support from experience and information from course materials. -Recognizes that there are other valid points of view.	-Identifies, appropriately, one's own position on the issue, drawing support from experience and information not available from assigned sources -Recognizes counterarguments that might be made and responds to them.
3) Identifies and considers OTHER salient perspectives and positions that are important to the analysis of the issue.			
<i>Scant</i>	<i>Minimally Developed</i>	<i>Moderately Developed</i>	<i>Substantially Developed</i>
Deals only with a single perspective and fails to discuss other possible perspectives, especially those salient to the issue.	Acknowledges that other perspectives exist, but fails to adequately present the case for these perspectives.	Appropriately addresses multiple perspectives, but omits at least one important perspective.	Addresses perspectives noted previously and additional diverse perspectives drawn from outside information.
4) Identifies and assesses the key assumptions.			
<i>Scant</i>	<i>Minimally Developed</i>	<i>Moderately Developed</i>	<i>Substantially Developed</i>
Does not surface the assumptions and ethical issues that underlie the issue, or does so superficially.	Identifies some but not all of the assumptions that have been made in their analysis. Only superficially considers the validity of those assumptions.	Identifies the assumptions made in the analysis and considers their validity, yet fails to surface important ethical issues.	Identifies and questions the validity of the assumptions and addresses the ethical dimensions that underlie the issue.

(1 - scant)	(2 - minimal)	(3 - Moderate)	(4 - Substantial)
5) Identifies and assesses the quality of supporting data/evidence and provides additional data/evidence related to the issue.			
<i>Scant</i>	<i>Minimally Developed</i>	<i>Moderately Developed</i>	<i>Substantially Developed</i>
<ul style="list-style-type: none"> -Merely repeats information provided, taking it as truth, or denies evidence without adequate justification. Confuses associations and correlations with cause and effect. -Does not distinguish between fact, opinion, and value judgments. -Does not identify sources or uses inappropriate sources. 	<ul style="list-style-type: none"> -Provides significant supporting evidence only the student's own perspective. Evidence for other perspectives is minimal. -Does not examine the evidence for bias or incompleteness. -Does not recognize value judgments. -Identifies sources but has some questionable sources. 	<ul style="list-style-type: none"> -Provides significant evidence for multiple perspectives. Questions accuracy and completeness. Of some evidence, but not all. -May have some problems with cause and effect. -May fail to properly identify some opinions and value judgments. -Uses and cites appropriate sources. 	<ul style="list-style-type: none"> -Provides significant evidence for multiple perspectives. Examines the evidence and source of evidence; questions its accuracy, precision, relevance, completeness. -Correctly identifies cause and effect. -Clearly distinguishes between fact, opinion, & acknowledges value judgments.
6) Identifies and considers the influence of the context on the issue.			
<i>Scant</i>	<i>Minimally Developed</i>	<i>Moderately Developed</i>	<i>Substantially Developed</i>
<ul style="list-style-type: none"> -Discusses the problem from the perspective of a single discipline. -Does not present the problem as having connections to other contexts-cultural, political, etc. 	<ul style="list-style-type: none"> Recognizes the importance of issues such as political and economic feasibility their question, but does not discuss their impact. 	<ul style="list-style-type: none"> Analyzes the issue considering relevant contexts, but fails to consider one important context. 	<ul style="list-style-type: none"> -Analyzes the issue with a clear sense of scope and context, including an assessment of the audience of the analysis. -Fully considers pertinent contexts such as political, economic, and social.
7) Identifies and assesses conclusions, implications and consequences			
<i>Scant</i>	<i>Minimally Developed</i>	<i>Moderately Developed</i>	<i>Substantially Developed</i>
<ul style="list-style-type: none"> Fails to identify conclusions, implications, and consequences of the issue or the key relationships between the other elements of the problem, such as context, implications, assumptions, or data and evidence. -Fails to reflect upon own work. 	<ul style="list-style-type: none"> -Draws incomplete conclusions or considers only some of the consequences of the conclusions. -Fails to reconsider assumptions identified earlier. -Fails to reflect upon own work. 	<ul style="list-style-type: none"> -Draws appropriate conclusions from evidence/data. Identifies and discusses some, but not all, consequences of these conclusions. -Fails to consider the limitations of their own work. -Identifies some directions for further inquiry. 	<ul style="list-style-type: none"> -Identifies and discusses conclusions, implications, and consequences considering context, assumptions, data, and evidence. -Objectively reflects upon their own assertions. Acknowledges the value judgments on which their position is based. -Identifies appropriate directions for further inquiry.

Appendix B: Grading Scheme for 7 Critical Thinking Traits in a Case Study

Talking Pt. Category	# Pts. Possible
	Worth total of 100 pts. Extra Credit Poss. 6 pts.
Main Ideas Expected	
1. Identify & Summarize Problem or Question at Issue	worth 10 pts.
Ethics of doctors being paid by investment companies to answer questions about research or general state of a current medical topic	(6) _____
Info for \$ -lots of income to doctor	(2) _____
Confidentiality of medical procedures, etc.	(2) _____
Insider info -- few people/investors with more information	(2) _____
Regulation of such conduct	(2) _____
Other ideas	(2) _____
2. Student's perspective and position --	worth 20 pts.
Provide perspective	(10) _____
Provide reasons why	(10) _____
3. Other important perspectives and positions --	worth 25 pts.
Provide 1 other perspective	(5) _____
Provide 1 other set of reasons	(5) _____
Provide 2 nd other perspective	(5) _____
Provide 2 nd set of reasons	(5) _____
Provide more perspectives	(5) _____
4. Identify key assumptions --	worth 10 pts.
Assumptions you make -- what you think is important	(5) _____
Assumptions others might make in other perspectives	- #1 (2.5) _____ - #2 (2.5) _____
5. Quality of supporting evidence	worth 10 pts.
Your point of view	(5) _____
Others' points of view	(2.5) _____
Additional evidence you found (other references)	(2.5) _____
6. Influence of context on issue -- where does each person/attitude come from?	worth 10 pts.
Your context	(5) _____
Other perspective context #1	(2.5) _____
Other perspective context #2	(2.5) _____
7. Conclusion -- identifies implications and consequences	worth 15 pts.
Possible outcomes	(5) _____
Implications -practical drawbacks or positives of outcome	(5) _____
Consequences of particular outcomes for particular parties	(5) _____