Implication of Critical Thinking for Applied Ethics in Science and Technology

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Abstract
As science and technology are descriptive, it is difficult for the undergraduates in Department of Science and Technology (DST) to learn Applied Ethics, which is of a completely different but philosophical approach in making moral judgment by applying Kant's moral theory, or theories of Utilitarianism, Contractarianism and Euthanasia, etc. Therefore, exploring reflective, interactive but practical method through fostering critical thinking in teaching Applied Ethics to students from DST is necessary. Since the introduction of critical thinking based upon revised Bloom's Taxonomy (Anderson & Krathwohl (Eds), 2001) and ethical reasoning (MacKinnon, 2012) in the first lesson, two classes of Yr. 2 major in Financial Mathematics, DST in BNU-HKBU United International College, have been trained to spend half an hour in each 3-hr session for brainstorming and discussion of various issues through critical thinking (Scriven & Paul, 1987) and ethical reasoning, and then present their ethical judgments in written or oral form. In the last two weeks, each group has to hand in a set of PowerPoints focused on any issues in science and technology selected by themselves through application of various ethical theories in moral decision making and then have their individual oral presentation. At the end of the course, each student is asked to answer a questionnaire modified from the one concerning critical thinking on ESL writing designed by Sham (2016) to evaluate the efficacy and establishment of critical thinking undergone through the six stages in Bloom's taxonomy and ethical reasoning in Applied Ethics in Science and Technology. (248 words)

Keywords: critical thinking, ethical reasoning, Applied Ethics, brainstorming, moral judgment

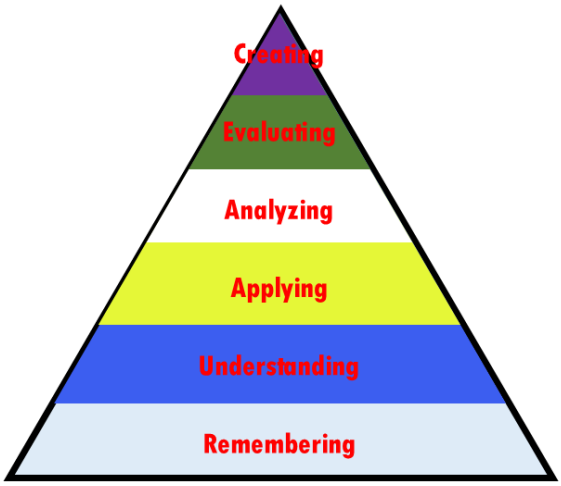
Introduction

As science and technology are descriptive, it is difficult for the undergraduates in Department of Science and Technology (DST) to learn Applied Ethics, which is a distinct category of ethical philosophy dealing with difficult moral questions and controversial moral issues that people actually face in their lives by judging whether they are good or bad, right or wrong, just or unjust. We have to use a completely different but philosophical approach in making moral judgment as a value, positive or negative, must to be placed in any normative judgment for evaluation. For making good and sound moral arguments, there must be true and valid premises and reasons given for the conclusion. Meanwhile, it is necessary to apply various famous philosophy and ethical theories, such as Plato's philosophy, Kant's moral theory, or theories of Utilitarianism, Contractarianism and Euthanasia, etc. in ethical reasoning and moral decision making. In order to make teaching and learning the course more interesting and effective, exploring reflective, interactive but practical method through fostering critical thinking in teaching Applied Ethics to students from DST is necessary.

Bloom's Taxonomy and ethical reasoning

According to the definition by Scriven and Paul (1987), "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'' (as cited in Foundation for Critical Thinking, 2009). Comparatively speaking, revised Bloom's Taxonomy best fits this definition as the hierarchical approach representing someone can involve a set of skills for organizing ideas, detecting inconsistencies, and solving problems logically and systematically after analyzing and evaluating alternative possibilities in different stages of thought process. Before taking any action, someone having critical thinking does not simply accept any arguments without questioning and making reasoned judgments based on evidence.

Fig 1. Revised Bloom's Taxonomy (Anderson, L. W. and Krathwohl, D. R., 2001)



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The hierarchy of revised Bloom's taxonomy consists of six levels representing different forms of thinking in an active process. Firstly, there are describing, finding, identifying, listing, retrieving, naming, locating and recognizing in the layer of Remembering. Secondly, subcategories such as classifying, explaining, inferring, comparing, paraphrasing and summarizing are found in Understanding. Thirdly, implementing, carrying out, using or executing is consisted in the category of Applying. Fourthly, the activities including attributing, comparing, deconstructing, integrating and organizing are in Analyzing. Furthermore, the action of critiquing, detecting, checking, experimenting, hypothesizing, judging, monitoring and testing may be involved in the level of Evaluation. Finally, constructing, inventing, devising, generating, planning and producing are activated in the highest level of Creating.

The method and participants

In the first lesson, 75 participants from two classes of Yr. 2 major in Financial Mathematics (FM), DST in BNU-HKBU United International College learned critical thinking based upon revised Bloom's Taxonomy (Anderson & Krathwohl (Eds), 2001) and ethical reasoning (MacKinnon, 2012). After 2-hr lecturing, they have been trained to spend half an hour to three quarters in each 3-hr session for brainstorming and discussion of various issues through critical thinking (Scriven & Paul, 1987) and ethical reasoning, and then present their ethical judgments in written or oral form. In the last two weeks, each group has to hand in a set of PowerPoints focused on any issues in finance, science and technology selected by themselves through application of various ethical theories in moral decision making and then they present as a group member individually. At the end of the course, each of the 75 participants answer a questionnaire modified from the one concerning critical thinking on ESL writing designed by Sham (2016) to evaluate the efficacy and establishment of critical thinking undergone through the six stages in Bloom's taxonomy and ethical reasoning in Applied Ethics in Science and Technology.

The questionnaire

In order to estimate whether the Yr. 2 undergraduates have gone through the six stages of critical thinking process of revised Bloom's Taxonomy in learning Applied Ethics in Science and Technology, and overall, the critical thinking in ethical judgments has been developed, a questionnaire modified from Sham (2016) has been designed. In the questionnaire, the statements are categorized into six levels orderly each includes three isolating sentences as last part for overall only contains two independent statements. Each questionnaire consists of 20 sentences. The participants have to choose an option for each sentence in the questionnaire which combines 5 points scale including 5=SA (Strongly Agree); 4=A (Agree); 3=N (Neither Agree nor Disagree); 2=D (Disagree); 1=SD (Strongly Disagree). The statements of the questionnaire arranged according to the six stages are presented as follows:

I. **Remember**
1. You first remember the terms & ethical theories taught.
2. The content, structure, and grammar of the samples are recalled.
3. You've learned from the mistakes & comments of the previous oral/writing tasks.

II. **Understand**
4. You have the ability to interpret the topics, issues, controversies & dilemmas.
5. Through group discussion, you understand the task from different views
6. By comparing & contrast facts and information, you determine the meaning.

III. **Apply**
7. The knowledge & philosophy from recall and understanding can be applied to the present discussion or task.
8. In brainstorming, you can use strategies, concepts, and theories to encounter a given issue.
9. You are able to employ the previously learned theories and knowledge in the present discussion, report or essay writing.

IV. **Analyze**
10. You can analyze and break the material into its constituent parts.
11. The pattern how different parts related to one another is detected.
12. An overall structure or the purpose of the written or oral presentation is found.

V. **Evaluate**
13. Concerning an argument, you list pros and cons in order to have a balance of both sides.
14. In making ethical judgments, you set up criteria for the defense of different views.
15. You can make choices through evaluation based on reasoned argument in group discussion.

VI. **Create**
16. You are able to put the elements together after brainstorming
17. Afterwards, you draw the conclusion to generate a novel, coherent report or essay.
18. Finally, you create and hand in an original writing product & ppts for oral presentation.

VII. **Overall**
19. You are able to think and present in a clear and logical manner for Applied Ethics.
20. This part establishes and enhances your critical thinking for ethical judgments.

Table 1. Financial Mathematics Students' Evaluation of Development of Critical Thinking in Applied Ethics

		N	Minimum	Maximum	Mean	Std. Deviation	Variance
I. Remember	Q1	75	2.0	5.0	4.093	.6813	.464
	Q2	75	2.0	5.0	4.093	.6189	.383
	Q3	75	2.0	5.0	4.053	.7333	.538
II. Understand	Q4	75	2.0	5.0	4.147	.6915	.478
	Q5	75	3.0	5.0	4.333	.6224	.387
	Q6	75	2.0	5.0	4.200	.6576	.432
III. Apply	Q7	75	3.0	5.0	4.107	.6892	.475
	Q8	75	3.0	5.0	4.227	.6488	.421
	Q9	75	3.0	5.0	4.200	.7166	.514
IV. Analyze	Q10	75	3.0	5.0	4.173	.5783	.334
	Q11	75	3.0	5.0	4.133	.6224	.387
	Q12	75	2.0	5.0	4.213	.6429	.413
V. Evaluate	Q13	75	3.0	5.0	4.333	.5774	.333
	Q14	75	3.0	5.0	4.333	.5774	.333
	Q15	74	3.0	5.0	4.243	.5688	.324
VI. Create	Q16	75	2.0	5.0	4.200	.6975	.486
	Q17	74	2.0	5.0	4.135	.6889	.475
	Q18	74	2.0	5.0	4.243	.6985	.488
VII. Overall	Q19	75	2.0	5.0	4.200	.7166	.514
	Q20	75	2.0	5.0	4.187	.6513	.424

Results and Discussion

Based upon Table 1, the number of Financial Mathematics (FM) students answering the questionnaires is 75. The maximum scores of all statements are 5 as strongly agree, whereas the minimums vary, either 2, disagree, or 3, neither agree nor disagree. For the evaluation of development of critical thinking in Applied Ethics, the maximums of 5 for the questions of all stages demonstrates that the majority of participants strongly agree that they have experienced all levels of revised Bloom's taxonomy in class.

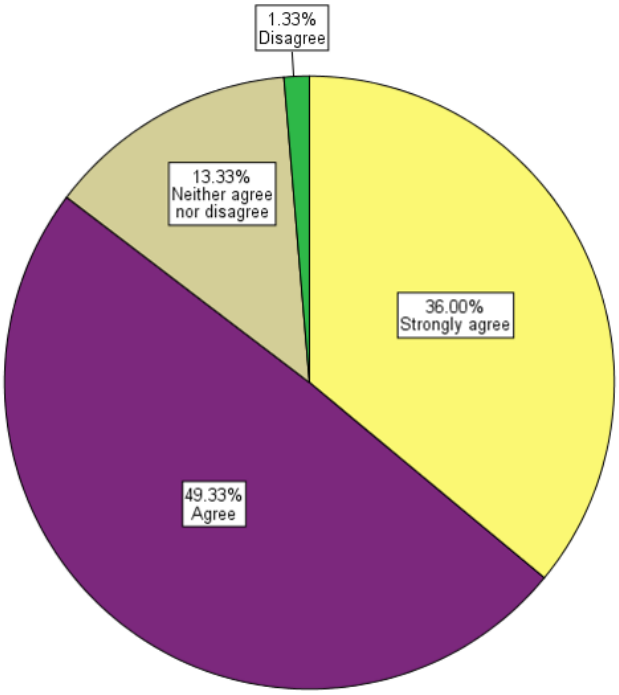
While 2 are the minimums of all questions in Remembering, Creating and Overall, the minimums for Q4 and Q6 in Understanding, and Q12 in Analyzing is also 2. It indicates that a small number of learners have found difficulties not only in different levels including Remembering, Creating and Overall, but also disagree that they have the ability to interpret the topics, issues, controversies and dilemmas. By comparing and contrasting facts and information, they disagree that they could determine the meaning. In analyzing stage, they disagree that an overall structure or the purpose of the written or oral presentation is found.

Meanwhile, some FM students neither agree nor disagree the statements in Applying and Evaluating, as well as Q5 in Understanding, Q10 and Q11 in Analyzing by given 3. That means they do not have any opinion in the levels of Applying and Evaluating. And also they are neutral that they understand the task from different views through

group discussion. In the Analyzing level, they neither agree nor disagree that they can analyze and break the material into its constituent parts and detect the pattern how different parts related to one another.

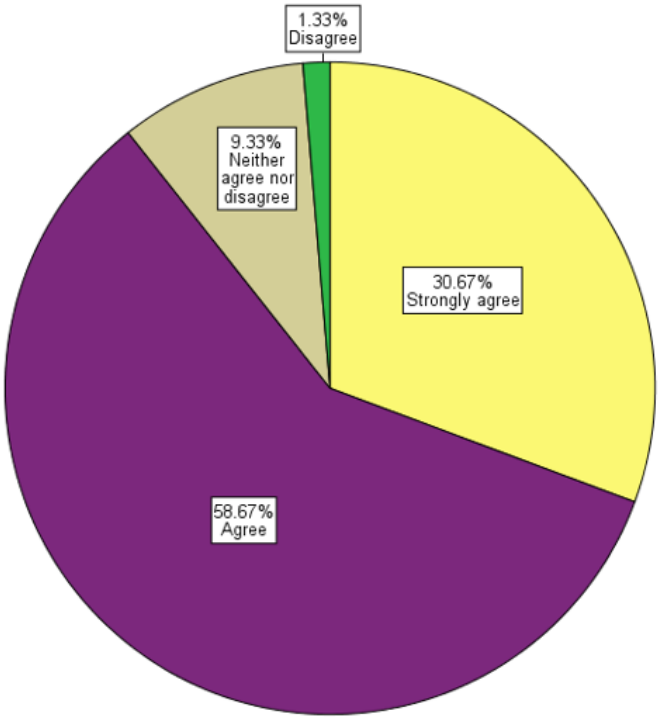
As the means of the 20 questions are between 4.053 and 4.333, all above 4, which are very high, shows that the majority of participants agrees or strong agrees that they have undergone through the six stages of revised Bloom's Taxonomy including Remembering, Understanding, Applying, Analyzing, Evaluating and Creating with Overall fostering and applying critical thinking in the Applied Ethics in Science and Technology.

Graph 1 The population Of FM Students agree or disagree they are able to think and present in a logical manner for Applied Ethics



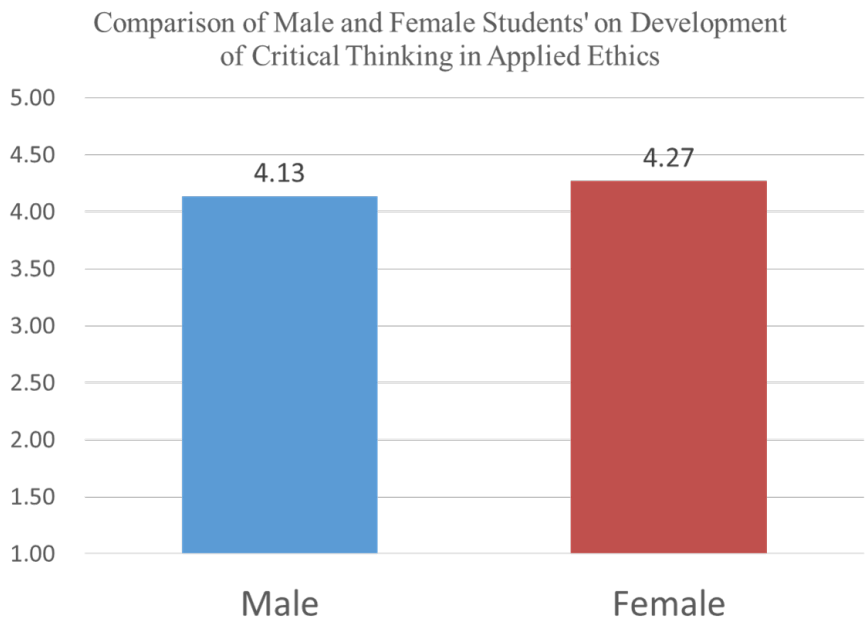
Representing the result of Q19, the distribution of the population in the above pie (Graph 1) shows that 36% of FM students strongly agree, 49.33% agree and 13.33% neither agree nor disgaree they are able to think and present in a logical manner for Applied Ethics, but a very small percentage of 1.33% disagree. It is clear that the large majority benefits from the learning process of Applied Ethics in Scienceand Technology through the revised Bloom's taxonmy for thinking and presenting logically, while the learners could justify the difficult issues and controversies in life with ethical reasoning systematically.

Graph 2 The population Of FM Students agree or disagree Group Discussion, Reports and Presentation enhance to establish their Critical Thinking in Ethical Judgment



The distribution of the population of the second pie (Graph 2) is based on the result of Q20: 30.67% of the FM learners strongly agree, 58.67% agree, 9.33% neither agree nor disagree that brainstorming through group discussion, reports and presentation enhance the establishment of their critical thinking for ethical judgments, whereas only 1.33% disagree. Overall, the majority of participants have found that their critical thinking has been fostered and established through the class activities including brainstorming and group discussion, writing reports and oral presentation. Comparing the two graphs, it is similar that both statements supported by the vast majority with slight difference as 36% strongly agree, 49.33% agree, 13.33% neither agree nor disgaree in the first graph, and 30.67% of the FM learners strongly agree, 58.67% agree, 9.33% neither agree nor disagree in second pie. Whereas, there is a small percentage of 1.33% disagree in both graphs. In other words, most FM students have established critical thinking undergone through the six levels in revised Bloom's taxonomy for Applied Ethics, and are able to apply their critical thinking as well as moral reasoning to present in a logical manner for making ethical judgments.

Graph 3



In comparison, the average of males in development of critical thinking based on the 20 statements in six stages with overall in the questionnaire of 75 FM participants is 4.13, and the average of females is 4.27 presented in the above bars (Graph 3), which demonstrates there is no significant difference between male and female FM students on the development of critical thinking in Applied Ethics in Science and Technology.

Conclusion

Based upon the results, two classes of Financial Mathematics (FM) students have undergone through the six stages according to revised Bloom's Taxonomy for implication of critical thinking in making moral judgments for different issues or controversies. Overall, they are able to think and present in a logical manner for Applied Ethics as well as have found that their critical thinking has been built in ethical decision making through the class activities including brainstorming and group discussion, writing reports and oral presentation.

As the FM participants learnt the revised Bloom's taxonomy in the first lesson, most of them enjoyed and benefited from brainstorming and group discussion in Applied Ethics, which is apart from the traditional methods. On the other hand, they agreed that group discussion and brainstorming helps blooming of critical thinking through the hierarchy - Remember, Understand, Apply, Analyze, Evaluate, and Create. As a result, they have widened their scope with more fun after brainstorming and better learning with practices in implementing critical thought are generally more interesting. The positive results of critical thinking in this research align with the findings of critical thinking in ESL education by Davidson (1994, 1995) and Sham (2016).

In conclusion, the students build their own thought through defense of different ideas, understanding of logic, and evaluation of judgments for solving problems through group discussion and brainstorming. Meanwhile, they have clear, independent and rational thinking before they make ethical judgments. Therefore, implication of critical thinking employing revised Bloom's taxonomy (Anderson & Krathwohl, 2001) in Applied Ethics is creative and effective. Once they have established critical thinking

and ethical reasoning, they can benefit from it in solving moral problems, handling dilemmas, and facing controversies of different ethical issues efficiently in their future life.

As recommended, teaching and learning Applied Ethics, especially in Department of Science and Technology (DST), is better to create more opportunities for brainstorming and interactions in group discussion about different moral issues by implication of critical thinking. Based upon the theories and principles of Plato, Kant and different schools, the learners could find out the best solutions for the ethical problems and controversies undergone through the hierarchy of revised Bloom's taxonomy.

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