2023 Annual Conference & Exposition
Baltimore Convention Center, MD | June 25 - 28, 2023
The Harbor of Engineering Education for 130 Years
ASEE
Paper ID #37362

The Development and Application of a Comprehensive Questionnaire Used to Evaluate the Effect of Engineering Ethics Courses

Dr. Jiaojiao Fu, Peking University

Jiaojiao Fu is a postdoctor at the Graduate School of Education, Peking University, Beijing, China. She received B.A. from China Agricultural University, M.Ed. and Ph.D. from Beihang University, China. From April 2017 to October 2017, she studied in the College of Engineering at the Ohio State University as a visiting scholar. Her academic and research interests include engineering ethics education, ethics of artificial intelligence, lifelong education.

The Development and Application of a Comprehensive Questionnaire Used to Evaluate the Effect of Engineering Ethics Courses

Abstract:

Different countries, colleges and universities, and even majors provide students with different kinds of engineering ethics courses. Practical course evaluation is conducive to presenting students' learning effects and subsequent course improvement. In the existing research and practice, the evaluation of engineering ethics education focusing on students' learning output has produced many positive results. On this basis, from the perspective of the sustainable development of the curriculum and benefiting more students, this study proposes that it is necessary to understand the evaluation of engineering ethics education from a broader meaning -- not only to evaluate the course of engineering ethics itself but also to evaluate the learning effect of students. By referring to the concepts, tools, and methods of engineering ethics curriculum evaluation, this study attempts to develop a comprehensive questionnaire survey.

The design of this comprehensive questionnaire is based on the goals of engineering ethics education. The topic presents logical progression according to each goal and content composition of engineering ethics education, from understanding to knowledge mastery to knowledge application. The questionnaire not only includes the evaluation of students' learning achievements but also covers the assessment of the implementation of the whole curriculum and curriculum elements, which reflects the characteristics of the whole curriculum and comprehensiveness. The reliability and validity of the comprehensive questionnaire are improved by referring to the engineering ethics course evaluation questionnaire in existing studies, soliciting experts' opinions many times, conducting multi-type pre-test, in-depth discussion feedback, and scoring twice.

The comprehensive questionnaire consists of three parts. The first part is about evaluating the course and students' learning experience, which includes not only the cognition and evaluation of the overall situation of the course but also students' recognition of the course and engineering ethics, self-evaluation, and feeling of course learning. This section is based on nearly 20 multiple-choice questions. The second part of the questionnaire mainly evaluates students' mastery of engineering ethics curriculum knowledge, ethical codes, and principles. Four multiple-choice questions (more than one answer) are selected by referring to the existing questionnaires, exam questions, and essential knowledge points in classic textbooks and taking into account the questionnaire's representativeness, difficulty, and length. The topic involves four aspects: engineers' aim (related to ethical principles, norms, obligation, utilitarianism, etc.), engineering ethics responsibility, the basic principles of dealing with the ethical problems of engineering, and the ethical rules of professional engineering associations. The third part contains two cases and four questions related to the cases. This paper selects two classic cases to design four essay questions from role conflict, identifying ethical dilemmas and contradictions, balancing interests, analyzing possible consequences from multiple perspectives, and proposing solutions to ethical dilemmas. In addition, detailed and quantifiable scoring criteria have been designed for the questionnaire.

The completed comprehensive questionnaire developed was used in an engineering university to test 511 students taking five different forms of engineering ethics courses. The effects and differences of various engineering ethics courses are obtained through the analysis of the questionnaire results. The application of the questionnaire survey has explained the effect of questionnaire design to a large extent but also reflected some limitations. Finally, combined with the questionnaire survey and interviews, the paper also suggests the possibility of further improvement of the comprehensive questionnaire.

Keywords: Evaluate Engineering Ethics Courses, Comprehensive Questionnaire, Develop the Questionnaire, Apply the Questionnaire, Improve the Questionnaire

Introduction

Different countries, colleges, universities, and even majors provide students with different kinds of engineering ethics courses. Some scholars [1] point out that engineering ethics cannot be isolated in a single curriculum, but must be scattered across many components of the educational program. Herkert [2][3] also believes that the ideal curriculum mode is to adopt the combination of various engineering ethics courses. Then, in the teaching practice of engineering ethics, the effects of these courses and the combination of various courses become common concerns. To a large extent, the evaluation of the effectiveness of the curriculum can deal with these problems.

Effective curriculum evaluation can timely promote the improvement of the engineering ethics curriculum. From the existing practice and research, the evaluation tools of engineering ethics education can be divided into two categories. The universal evaluation represented by standardized evaluation tools, usually presented in the form of ‘scale & case’. Most evaluation attributes and dimensions are set according to the objectives of engineering ethics education and the requirements of ABET. The usual evaluation methods are as follows: *Defining Issues Test* (DIT), *The Engineering and Science Issues Test* (ESIT), *The Pittsburgh-mines Engineer Ethics Assessment Rubric*, etc. The other is the non-standardized tool for evaluating the effect of daily course teaching for specific course. Generally, the evaluation scale is small, and the methods such as questionnaire surveys, interviews, and pen-and-paper tests can be adopted. These tools provide good inspiration for this study.

From the perspective of concrete implementation, it includes a comparative study of the performance of current students after taking courses and continuous follow-up surveys of graduates. Robert [4] had conducted a follow-up survey of Stanford University graduates. The results showed that these engineering graduates had different opinions on ethical topics and what they included. He believed that survey analysis could promote the education of engineering ethics. Roach [5] used a similar experimental approach to evaluate the effectiveness of engineering ethics education for engineering students. Hashemian [6] et al. adopted the interview method and concluded that learning engineering ethics courses could change engineering students' understanding of professional engineering responsibilities. Jason et al. [7] used ESIT to evaluate the teaching effect of engineering ethics courses. Davis et al. [8] had investigated the improvement and progress made by students in engineering ethics after graduation. They concluded that students who had studied engineering ethics had

clear advantages over students who had not studied engineering ethics in ethical knowledge and sensitivity after graduation. The results obtained by these tools and methods in concrete applications are primarily favorable. These evaluations mainly focus on evaluating students' learning performance in engineering ethics.

This study believes that the objectives of engineering ethics education and students' learning output should be consistent and corresponding. From this point of view, students' learning outcomes should be taken as the core of evaluation in engineering ethics education. However, from the perspective of sustainable curriculum development and benefiting more students, this study points out that it is necessary to understand the evaluation of engineering ethics education from a broader sense -- to evaluate the engineering ethics course itself and the learning effect on students. The evaluation of the engineering ethics course means evaluating the whole curriculum implementation and curriculum elements. The evaluation of this dimension is conducive to analyzing the factors affecting students' learning effect. It can also suggest specific and clear suggestions for subsequent course improvement. Therefore, this study attempts to develop a comprehensive questionnaire survey by referring to the concepts, tools, and methods of engineering ethics curriculum evaluation in existing studies.

Methodology

Convergent parallel mixed methods were adopted to evaluate the effect of engineering ethics courses in this paper. Mizikaci [9] also recommended that researchers used statistical and qualitative research methods to provide deeper analysis and information when evaluating training programs.

In the process of questionnaire development, the Delphi method was adopted to improve the reliability and validity of the questionnaire. The opinions of many experts and teachers engaged in the research and teaching of engineering ethics education were solicited and collected many times, and the questionnaire was modified. Five student volunteers participated in the questionnaire pre-test, discussion, and feedback.

The developed questionnaire was used in an engineering university as a questionnaire survey. A total of 511 students taking five different kinds of engineering ethics courses participated in the test.

In addition, to further analyze the questionnaire results, the author also conducted interviews with relevant teachers and students. Since this is not the focus of questionnaire development and application, the implementation and contents of the interviews are not presented in this study.

Results and Discussions

The Development of the Comprehensive Questionnaire

(1) The design basis of the comprehensive questionnaire

The questionnaire design in this study not only adheres to the first principle of questionnaire design to ensure that the questionnaire questions are consistent with the

research objectives but also strives to make sure that the questionnaire questions correspond to the appropriate objectives of engineering ethics education and the elements of the curriculum. First of all, the questionnaire design reflects the characteristics of the whole curriculum. That is, in order to fit the research objectives, the questions in the questionnaire cover various elements of the curriculum model and the course pattern, including not only the overall evaluation of the curriculum but also a further detailed investigation of the curriculum understanding, teachers, contents, form, teaching method, teaching environment, and curriculum evaluation. Second, according to the various objectives and contents of engineering ethics education, the questionnaire questions presented a logical progression. From recognition to knowledge mastery to knowledge application, students' learning effects in various curriculum modes were evaluated individually, and the correlation among the achievement of various objectives was analyzed.

(2) Contents of the comprehensive questionnaire

The main body of the questionnaire is divided into three parts. There are slight differences in the questionnaires for different courses.

The first part of the questionnaire is about course evaluation and course learning feelings. It is not only the understanding and evaluation of the overall situation of the course but also includes students' understanding and recognition of the course and engineering ethics as well as their self-evaluation and feelings about the course learning. Due to the different types of courses, the question settings of this part are also different. Different versions of the questionnaire do not consider the skipping question settings, and 20 and 19 questions are designed respectively. Except for the blank-filling questions for the majors and grades, 2-3 are multiple-choice, and others are single-choice. According to the situation of skipping questions, the actual answers of respondents ranged from 6 to 20 questions. The skipping questions of the questionnaire are to distinguish ideological and political courses from the other four types of courses. It should be pointed out in particular that the *ideological and political courses*, as a kind of special courses, exist in the region and schools where this study is located. Therefore, different versions of the questionnaire have been designed. If there is no ideological and political course, it is enough to keep the first 13 questions in Part One of the questionnaire.

Figure 1: The first part of the questionnaire

Part One	**Course Evaluation and Learning Feelings of Students (all are single choice questions unless otherwise indicated)**	**Notes**
1	Your major and grade:	
2	Do you think engineering ethics education is necessary? A. Necessary B. General C. Not necessary	
3	In your opinion, in what form should engineering ethics education courses be carried out? A. Required Courses for majors B. Public required courses C. Optional Courses for majors D. Public electives E. Others	
4	Are you interested in this course? A. Interested B. General C. Not interested	
5	Do you think the teacher of this course is competent to teach this course? A. Very competent B. Basically competent C. Average D. Not quite up to it	

6	Are you satisfied with the teaching methods of your teachers? A. Very satisfied B. Satisfied C. Average D. Not satisfied E. Not satisfied at all	
7	Can the contents of this course meet your needs of learning engineering ethics? A. Very B. Basically C. Averagely D. Not	
8	What problems did you encounter in the course study? (Multiple choices for this question) A. Too few contents B. Difficult to understand C. Single teaching method D. Excessive theoretical contents E. Others (please specify)	
9	Have you improved your interest in engineering ethics after completing this course? A. A lot of improvement B. Average C. No improvement	
10	Do you think you have learned anything from this course? A. A lot B. A little C. Average D. Little was gained	
11	How do you think this course will help to improve personal engineering ethics awareness and ability? A. Very helpful B. Helpful C. Average D. Little help E. No help at all	
12	In addition to this course, have you taken any other courses related to ethics or engineering ethics? A. Yes, course name or teacher's name: (Skip to question 13) B. No (skip to question 14)	Skip
13	What is the reason for you to take many courses related to ethics/engineering ethics? (Multiple choices for this question) A. Interested in such courses B. Easy to obtain credits C. Recommended by classmates or people around D. There is no other course to choose E. I heard that the teacher of this course is excellent F. Other reasons (please specify)	
14	In the several *ideological and political courses* you have taken, have the teachers mentioned or explained any content related to ethics or engineering ethics? A. Mentioned or explained (skip to question 15) B. No (skip to question 20)	Skip
15	In what form is the content of ethics or engineering ethics taught in *ideological and political courses*? (multiple options are available) A. Mentioned by the teacher B. Special subject C. Case study D. Theoretical Introduction E. Others (please specify)	
16	In your opinion, contents related to ethics/engineering ethics in *ideological and political courses*: A. A lot B. A few C. Very few D. Hardly any E. Not at all	
17	Do you think the ethics/engineering ethics contents in the ideological and political courses can meet your learning needs in engineering ethics? A. Very B. Basically C. Averagely D. Not	
18	Do you think *the ideological and political courses* have increased your interest in engineering ethics? A. A lot of improvement B. Average C. No improvement	
19	How do you think *ideological and political courses* help you to improve your awareness and ability of engineering ethics? A. Very helpful B. Helpful C. Average D. Little help E. No help at all	
20	If you have the opportunity in the future, do you want to take other ethics/engineering ethics related courses? A. Yes B. No	

The second part of the questionnaire mainly evaluates students' grasp of engineering ethics curriculum knowledge, ethical norms, and principles, including two first-level indicators: ‘ethical knowledge principles’ and ‘ethical norms’. Four indefinite multiple-choice questions are selected by referring to existing questionnaires, test questions, and essential knowledge points in classic textbooks and taking into account the representativeness, difficulty, and duration of the questionnaire. The topic involves

four aspects: engineer goals (related to ethical standards, norms, obligations, utilitarianism, etc.), engineering ethical responsibility, basic principles for dealing with ethical engineering issues, and ethics regulations of professional engineering associations, in order to test students' understanding of basic knowledge, ethical principles, responsibilities, stakeholders and other aspects of engineering ethics, as well as their cognition and mastery of engineering ethical norms. The questions in this part are the same in different versions of the questionnaire in this study.

In addition to referring to existing questionnaires, test questions, and essential knowledge points in classic textbooks, the ethics questions on the Fundamentals of Engineering Exam (example 5), considered to measure student knowledge, could also serve as an enlightening thought. If the questions such as aligning those results with specific courses and contents innovation were solved, it could play a good role in the comprehensive questionnaire design.

Example 1: *The engineering professional code requires that ( ) be given priority.*
A. Operational standards of the project B. Economic benefits of the project
C. Public safety, health and well-being D. Technological innovations in engineering

Example 2: *In the following types，which is/are engineering ethical responsibility(ies): ( ).*
A. Professional ethical responsibility B. Social ethical responsibility
C. Environmental ethical responsibility D. Corporate ethical responsibility

Example 3: *The basic principle(s) for dealing with engineering ethics is/are ( ).*
A. Humanitarianism -- the basic principle of dealing with the relationship between engineering and people
B. Social justice -- the basic principle of dealing with the relationship between engineering and society
C. Harmonious development between man and Nature -- the basic principle of dealing with the relationship between engineering and nature
D. The principle of interest orientation, giving priority to the interests of employers

Example 4: *Which of the following statements is/are appropriate or accurate regarding the code of ethics of the professional engineering association? ( )*
A. A government department must approve it before it is enacted
B. is a constraint on the professional activities and behavior of practitioners engaged in this profession
C. is the moral commitment of the practitioners of the profession to the profession, which is a voluntary organizational contract
D. is a mandatory legal requirement

Example 5*: According to the Model Rules, Section 240.15, Rules of Professional Conduct, licensed professional engineers are obligated to:****(from Fundamentals of Engineering Exam)***
A. ensure that design documents and surveys are reviewed by a panel of licensed engineers prior to affixing a seal of approval
B. express public opinions under the direction of an employer or client regardless of knowledge of subject matter
C. practice by performing services only in the areas of their competence and in accordance with the current standards of technical competence
D. offer, give, or solicit services directly or indirectly in order to secure work or other valuable or political considerations

The third part of the questionnaire consists of two cases and four questions related to the cases. Case-based scale is also widely used by other engineering ethics educators.

This part mainly tests the goal of engineering ethics ability level. Two classical cases are selected from classical textbooks at home and abroad. Four short answer discussion topics are designed from role conflict, identification of ethical dilemmas and contradictions, interest balancing, multi-perspective analysis of possible consequences, and proposed solutions to ethical dilemmas. As in the second part, the cases and questions selected were the same in the different versions of the questionnaire.

Cases of engineering ethics education generally come from two approaches: one is to select existing cases in textbooks at home and abroad directly; the other is to develop new engineering ethics teaching cases through text processing and design of hot social events or news reports related to engineering ethics according to teaching needs. The former is more mature, while the latter requires a higher level of competence from the case developer. In order to improve the effectiveness of the questionnaire design, the cases used in the questionnaire scale in this study are all from international classical textbooks. According to the research needs, the existing mature scale case design is referred to. Based on repeatedly reading international engineering ethics textbooks, three cases are selected, namely ‘Employment opportunities’, ‘Build a public waste landfill’, and ‘Forklift Operator’. Considering the length of the questionnaire and the similarity of the questions, this study finally chose two cases: ‘employment opportunities’ and ‘build a public waste landfill’.

The first case is ‘employment opportunities. This case first appeared in 1992 in Pritchard's *Teaching Engineering Ethics: A Case Study Approach* [10], which was later cited in *Engineering Ethics: Concepts & Case*s (3rd edition), published by Harris and Pritchard et al., and translated into Chinese in *Engineering Ethics: Concepts and Cases (3rd Ed)* [11]. This case is also retained in the translation. Ten years later, in 2016, this case was cited again in *Engineering Ethics* [12], edited by Li Zhengfeng, Cong Hangqing, Wang Qian, etc., and a detailed analysis of this case was made in the relevant chapters combined with chapter contents. After more than 20 years, this case is still accepted and adopted by scholars from many countries, which indicates that this case is typical and analyzable to some extent. Therefore, the questionnaire of this study also adopts this case to investigate the question of ‘engineers coping with role conflict’.Based on the principle of ‘using natural and familiar language to design questions, accurately and concisely’, the questionnaire first changed the names of people and companies that are easily confused and have a large number of words after translation into easy-to-understand and easy-to-remember names, which were displayed in bold in the questionnaire to facilitate the reading of respondents and reduce unnecessary comprehension and memory time. Then, according to the mother tongue expression habit, the language expression in the case is adjusted based on maintaining the original meaning. After the pre-test, given the excessively long questions, the parts of the case that did not affect the questions' answers were further depleted. The original case of 1,418 words was finally shortened to the abbreviated version of 645 words.

The second case is ‘Build a public waste landfill’, which also appeared in *Engineering Ethics: Concepts and Cases (3rd edition)* [11] and *Engineering Ethics* [12], adjusted from 488 words to 308 words in the original translation, and analyzed in detail in relevant chapters of *Engineering Ethics* textbook combined with chapter contents. When using this case in the questionnaire, personal names, place names, numbers, and

related expressions were simplified to form a shorter case of 251 words.

Example: *Question 1 of Case 1: Please list the role conflicts of the protagonist and briefly analyze them.*

Question 1 of Case 2: From the protagonist's point of view, please briefly list all the contradictions and conflicts of interest involved in the case, and prioritize these contradictions based on the ethical knowledge you have mastered.

Question 2 of Case 2: Three action plans have been given in this case. First, the government proposed to build a public waste and garbage landfill in a sparsely populated area. Second, the rich proposed to rebuild the garbage and waste landfill to the city where the poor live; Third, the rich have also proposed relocating the landfill to the poorest, sparsely populated suburbs of W city. Put yourself in the protagonist's shoes and briefly compare the three options.

Question 3 of Case 2: Based on the above analysis, what action plan would you take if you were the protagonist?

(3) Score of the comprehensive questionnaire

The scoring criteria of the questionnaire play a crucial and decisive role in processing the questionnaire results. In order to accurately evaluate the performance of students' answers to the questionnaire and make the results of each questionnaire more distinguishable, the total score of the questionnaire was set as 200 points. Then the total score of the student's answers was calculated and converted into 100 points which were more in line with the tradition and habit of education and teaching. The course knowledge section includes four indefinite multiple-choice questions, 10 points for each question, no answer, wrong choice, multiple choice, the missed choice will not score, 10 points for each correct answer, and 40 points in total. The case simulation part includes two cases and assigns points to each question according to the number of knowledge points investigated in each case. The first case contains three investigation points, 10 points for each point and 30 points in total. The second case consists of three questions. The first question covers seven investigation points, 10 points for each investigation point, with a total of 70 points; the second question covers three investigation points, 10 points for each investigation point and 30 points in total; the third question covers three investigation points, 10 points for each investigation point, with a total of 30 points; the second case has a total of 130 points. The total score of the simulation part is 160.

(4) The validity and reliability of the comprehensive questionnaire

In the whole process of questionnaire design, distribution, and scoring analysis, the validity and reliability of questionnaires are always paid attention to. The validity of the questionnaire refers to the validity and correctness of the questionnaire. It is generally believed that reliability analysis is used to measure whether the sample answers are reliable. As for the scale data, it is mainly quantitative. In the questionnaire in this study, the case analysis occupies a large proportion, so the reliability of the questionnaire measurement is ensured by strengthening the questionnaire design, refining the pre-test, timely correction, and strict grading instead of coefficient analysis.

First of all, learn from domestic and foreign questionnaires. In order to ensure the

reliability and validity of the questionnaire, the overall evaluation and learning experience of the course were prepared independently in the questionnaire design. The part of curriculum knowledge mainly refers to questionnaires in existing studies and exam questions of engineering ethics-related courses in universities such as B University to select questions that fit the research objectives. Of course, in the actual operation, we can also learn from FE and other examinations. On the one hand, the few existing questionnaires have usually been tested for reliability and validity. On the other hand, the course examination questions of those universities with advanced and mature engineering ethics education are usually designed by teaching teams or lecturers who are well-known experts in this field and have strong authority. In the case simulation part, the standardized evaluation tools of engineering ethics education, mainly in scale + case, are adopted by many colleges and research organizations in the United States. The first step of developing these evaluation tools is to select case materials for testing. This study draws on using cases in standardized evaluation tools in the United States. In addition, to ensure the case's applicability and effectiveness, this study selects the cases used or quoted in classic textbooks and mainstream textbooks of many countries. At the same time, related knowledge points of the case are described in reference textbooks, and the case itself is analyzed. Questions and scoring basis are designed in line with this study's objectives to reduce the questionnaire design's subjectivity to enhance the scientific nature of the questionnaire.

Second, seek expert advice many times. The Delphi method was adopted in this study to ensure the content validity of the questionnaire. After refining the research objectives, the opinions of many experts and teachers engaged in researching and teaching engineering ethics education were solicited and collected. Based on the experts' opinions, the questionnaire was modified and adjusted repeatedly in the topic setting and expression to improve the validity of the questionnaire in terms of contents. Due to the pandemic, the Delphi method has been used for expert consultation with various tools, including email, instant messaging and online meetings.

Third, conduct multiple types of pre-test and in-depth discussions of feedback. Based on referring to questionnaires and evaluation scales in existing studies, the first version of the questionnaire, designed and completed according to the research objectives of this paper, was used for pre-testing. An engineering student, a student with engineering background, and a liberal arts student with an educational background were separately selected to give simulated answers. After the answers, the feelings and opinions of the three students on the questionnaire were collected and discussed with the respondents question by question and analyzed repeatedly. The answers and opinions of students from different majors provided excellent inspiration for revising the questionnaire, and the time of answering the questionnaire was roughly determined for the first time. The revised questionnaire was then answered by two students who had already taken the first version of the questionnaire and a new engineering student and a new liberal arts student with educational background. Then the same discussion and analysis were carried out as in the first pre-test, and the question of the response time was again focused on.

Fourth, score twice. In addition to clarifying the scoring criteria, this study further ensured the questionnaire's reliability by examining raters' reliability. As this study is

independent research, the rater reliability method adopted is to calculate the correlation coefficient of two grades by one rater. According to the scoring standard, the collected questionnaires were scored twice. In the two scoring processes, the questionnaires were first renumbered to disarrange the original order, and then the questionnaires were scored again ten working days later. According to the changes in the two scores, it was decided whether to adopt the third score or ask for expert guidance. However, the results showed that the scores of all questionnaires did not change, thus ensuring the consistency and stability of the scoring results. In the future, if further in-depth study, it is necessary to form a rubric and sample scoring across a set of experts to better calibrate the scores.

The Application of the Comprehensive Questionnaire

According to the differences among these courses in each element of the curriculum models, the current curriculum models of engineering ethics education were defined into five categories at X University. They were ‘separate courses in engineering ethics model’, ‘engineering ethics courses combined with engineering professional courses model’, ‘engineering ethics courses combined with the non-engineering professional courses model’, and ‘the general or elective courses model related to ethics and philosophy’, and ‘ideological and political theory courses as a special model’.
The students who participated in the survey included students taking various courses and students only taking the ‘ideological and political courses’. From the grade distribution, from freshman to graduate students were covered; From the point of view of departments and majors, nearly 20 engineering majors were covered in ten departments, departments or classes.

Due to the epidemic's impact, the questionnaire survey was conducted through the distribution of paper and online questionnaires. Firstly, invalid questionnaires were eliminated, and then statistics were made on the ‘course evaluation part’ of the valid questionnaires. The ‘course knowledge’ and ‘case simulation’ parts were scored twice according to the scoring standard, and all the scores were counted.

All courses and students are coded and registered to facilitate differentiation and statistics. First of all, A, B, C, D, and E are used successively to mark the five classes of courses. The specific courses belonging to this kind of course mode are numbered successively in the form of ‘category number + Arabic numerals’. For example, A1 and A3 represent the first ‘separate courses in engineering ethics’ and the third ‘separate courses in engineering ethics’. It should be specifically noted that ‘Ideological and political courses’ is the E category. Only E stands for ‘ideological and political courses’. Students participating in the survey are numbered in sequence as ‘course number +S+ Arabic numeral’.

Figure 2: Statistics on the number of questionnaires of various courses

Course name coding	Curriculum model categories	Number of valid questionnaires
A1	separate courses in engineering ethics model	90
A2		86

B1	engineering ethics courses combined with engineering professional courses model	114
B2		84
C1	engineering ethics courses combined with the non-engineering professional courses model	5
D1	the general or elective courses model related to ethics and philosophy	11
E	ideological and political courses	121
Total	\	511

Outcomes from Applying the Comprehensive Questionnaire in X University

In the first part of the questionnaire, we surveyed students' self-evaluation and feelings about the course learning effect through multiple choice questions. The main concern is what students gain from learning the course, whether their interest, awareness, and ability of engineering ethics have been improved after taking the course, and whether they will continue to take engineering ethics-related courses. Although this part is the subjective evaluation of students, the questions investigated are all related to the course effect. The percentage statistics of each result data are shown in Figure 3.

Figure 3: Percentage statistics of each result data in the questionnaire survey -Part 1

Courses	It is necessary for engineering ethics education	Interested in this engineering ethics course	The content of the courses can meet my needs to learn engineering ethics (very satisfied and basically satisfied)	Learned (many and some)	My interest in engineering ethics is greatly improved after the course	Taking courses is very helpful and helpful to improve the awareness and ability of engineering ethics	I am willing to take other engineering ethics courses in the future
A1	55.56	37.78	61.11	47.1	31.11	46.67	72.22
A2	76.74	53.49	77.38	80.23	48.84	75.58	87.21
B1	57.02	54.39	73.69	90.35	52.63	84.21	70.18
B2	78.57	46.43	67.86	89.47	50	79.76	85.71
C1	80	60	60	100	100	100	100
D1	45.45	72.73	36.36	90.91	9.09	18.18	90.91
E	49.59	\	79.34	\	15.7	17.36	67.77

Firstly, the effects of these courses (B1S, B2S, and part ES) were investigated and evaluated by questionnaires. The survey results showed that students scored poorly in the "course knowledge" section (Part Two), with about half of the students scoring less than 50 percent of the total score, which means that about half of the students

mastered less than half of the knowledge. This kind of performance is unacceptable in almost all courses of instruction in all schools, either because the exam questions are too complicated or not following the curriculum, because of poor learning, or for other reasons. Before the questionnaire survey began, we conducted a pre-test for the questionnaire and solicited the opinions of relevant experts and teachers. Based on the objectives and requirements of engineering ethics education, it was generally considered that the difficulty of this part was appropriate. At the same time, a few experts thought that the difficulty was relatively easy. Considering that engineering ethics education has not been fully popularized in China, it is speculated that the students who start to learn engineering ethics may feel unfamiliar and challenged. Therefore, in the follow-up investigation, this study decided to add an evaluation of the difficulty of the questions in the questionnaire without modifying the questions. Since the questions of this part of the questionnaire were set based on the expected objectives and contents of engineering ethics education rather than the teaching contents of each course, the unsatisfactory results of the initial survey also inspired us for the subsequent analysis and investigation of the objectives and contents of each course. Therefore, this study retained this part of the "moderate difficulty slightly easier" questions in the follow-up survey.

Example: *How difficult do you think it is to answer the questions in this case?*
A. Very simple B. Simple C. The difficulty is appropriate
D. Difficult E. Very hard

According to the statistics of the scores of A1S, A2S, C1S, D1S, and the other parts of ES, the results show that students' evaluation of difficulty does not correlate with the scores of this part. Therefore, it is speculated that students' subjective evaluation of the difficulty of the subject is not the factor affecting the score, or we should explore the reason from the course itself.

Figure 4: Course knowledge part score statistics -Part 2

Course	Course Knowledge score（total 20）					
	Percentage of the score distribution					Average score
	0	5	10	15	20	
A1	3.33	11.11	25.56	37.78	22.22	13.22
A2	2.33	15.12	29.07	36.05	17.44	12.56
B1	15.79	24.56	29.82	22.81	7.02	9.04
B2	21.43	28.57	25	21.43	3.57	7.86
C1（3）	0	66.67	0	33.33	0	8.33
D1	27.27	36.36	27.27	9.09	0	5.91
E	25.62	37.19	22.31	10.74	4.13	6.53

Based on the scoring method mentioned above, the scores of simulated cases are statistically analyzed, as shown in Figure 5.

Figure 5: Simulation case part score statistics -Part 3

Course	Overall average score（Total 80）				
	Percentage of the score distribution				Simulated case average score
	0-15	20-35	40-55	60-80	
A1	55.56	31.11	8.89	4.44	18.67
A2	9.30	33.72	38.37	18.60	40.99
B1	56.14	29.82	10.53	3.51	19.39
B2	53.57	32.14	10.71	3.57	18.75
C1	33.33	33.33	33.33	0	26.67
D1	45.45	36.36	18.18	0	17.27
E	50.41	33.06	5.79	2.48	16.98

Figure 6: Total average score statistics -Part2 & Part 3

Course	Total（100）		
	Simulated case average score **Part 3**	Course Knowledge average score **Part 2**	Overall average score
A1	18.67	13.22	31.89
A2	40.99	12.56	53.55
B1	19.39	9.04	28.43
B2	18.75	7.86	26.61
C1	26.67	8.33	35
D1	17.27	5.91	23.18
E	16.98	6.53	23.51

According to the above statistics, the effects of the course knowledge part are as follows: A1>A2>B1>C1 >B2>E >D1, the effects after removing C1 are: A1>A2>B1>B2>E>D. The effects of simulation case analysis are as follows: A2>C1>B1>B2>A1>D1>E, the effects after removing C1 are: A2>B1>B2>A1>D1>E. The overall effects of the overall average score ranking in Figure 6 are as follows: A2>C1>A1>B1>B2>E>D1, the effects of removing C1 are: A2 >A1>B1>B2>E>D1. Therefore, the comparison results of the overall effects of various curriculum modes are as follows: the effect of 'engineering ethics curriculum mode offered alone' is better than that of 'engineering ethics curriculum mode combined with professional engineering courses', which is better than that of 'ideological and political curriculum mode' and 'the general or elective courses model related to ethics and philosophy'. Although the overall effects of engineering ethics education in China could be better due to the impact of the implementation time, there are apparent differences in the effects of various curriculum modes. This study focuses on the construction and application of the comprehensive questionnaire, and provides a template or idea to share. Therefore, the differences among different courses will not be analyzed here. The author may make a detailed analysis in the course comparison article later.

Limitations

The comprehensive questionnaire, developed during the COVID-19 pandemic, only investigated various engineering ethics courses offered by X University. Although X University is representative, and this study also tries to expand the sample size, it still needs to be expanded to more universities. In addition, other engineering ethics courses are usually elective due to the nature of the course, except for the engineering ethics course offered separately. The number of students is often flexible, which leads to a significant difference in the number of students in various courses. Thus, the number of survey samples of various course modes could be more balanced, making it possible to conduct more in-depth and complex data analysis. For example, the number of students enrolled in the C course in this study is minimal. After that, the comprehensive questionnaire is applied to evaluate engineering ethics courses in more schools, and more feedback information is obtained, which is conducive to improving the comprehensive questionnaire. As mentioned above, this study is independent research. Although the author tries her best to improve the rater reliability by calculating the correlation coefficient of twice scoring, it seems more better to form a rubric and sample scoring across a set of experts to better calibrate the scores.

Conclusions

Based on the goals of engineering ethics education, this study designed a three-part comprehensive evaluation questionnaire for the engineering ethics curriculum with the dual tasks of curriculum evaluation and student output evaluation. In the investigation process, the teachers and students who participated in the survey gave good feedback to the comprehensive questionnaire. The analysis of the questionnaire results can also reflect the effect difference of various courses and present helpful information for the course effect and student performance. Moreover, we can also explore the role of the comprehensive questionnaire from two aspects. First, the comprehensive evaluation of the specific curriculum situation and the test of students' learning results of engineering ethics directly affect the improvement of the curriculum; Secondly, the comparison of the effects of various engineering ethics courses is conducive to the appropriate course setting and cohesion planning.

As mentioned above, the questionnaire of various courses has made subtle and targeted adjustments based on the comprehensive questionnaire, which also shows that the comprehensive questionnaire can provide a basic model suitable for evaluating various courses. In the actual curriculum evaluation, teachers can adjust the specific content and number of questions according to the curriculum contents and evaluation objectives to better serve the evaluation of the taught curriculum. In addition, necessary and timely interviews or further in-depth exploration after the questionnaire are conducive to analyzing the questionnaire results and excavating the fundamental problems in course evaluation to improve the engineering ethics curriculum and achieve the goal of engineering ethics education.

Acknowledgements

The author acknowledges the constructive suggestions from the anonymous reviewers, whose insights helped to improve the quality of this paper. The author also appreciates the thoughtful feedback from the experts, whose insights helped to improve the quality

of the comprehensive questionnaire. Sincerely thanks the teachers and students who participated in the questionnaire survey. Thanks are also due to the support from the National Experimental Base for Intelligent Society Governance（Education）and Digital Learning Research Center in Peking University.

References

[1] Lin J, Yi FQ. “Future-oriented Engineering Ethics Education”. In: *Research in Higher Education of Engineering* (2021), pp. 1-11

[2] J. R. Herkert, “Continuing and emerging issues in engineering ethics education and research: integrating microethics and macroethics”, In: *IEEE Power Engineering Society General Meeting*, 2004., Denver, CO, USA

[3] Herkert J R. “Engineering ethics education in the USA: Content, pedagogy and curriculum”. In: *European Journal of Engineering Education* (2000), pp. 303-313

[4] Robert E. McGinn. “ ‘Mind the gaps’: An empirical approach to engineering ethics, 1997-2001”. In: S*cience and Engineering Ethics*(2003), pp. 517-542

[5] Steve Roach, Jules Simon. “Teaching and assessing graduate ethics in Engineering, Science and Technology”. In: *Innovative Techniques in Instruction Technology, E-learning, E-assessment, and Education*, (2008) , pp.509-513

[6] Golnaz Hashemian, Michael C. Loui. “Can Instruction in Engineering Ethics Change Students’ Feelings about Professional Responsibility?”. In: *Science and Engineering Ethics* (2010), pp. 201-215

[7] Jason Borenstein, MJ Drake, R Kirkman, et al. “The Engineering and Science Issues Test (ESIT): A Discipline-Specific Approach to Assessing Moral Judgement”. In: *Science and Engineering Ethics* (2010), pp. 387-407

[8] Davis M, Feinerman A. “Assessing Graduate Student Progress in Engineering Ethics”. In: *Science and Engineering Ethics*(2012), pp. 351-367

[9] Mizikaci, F. “A systems approach to program evaluation model for quality in higher education”. In: *Quality Assurance in Education* (2006), pp. 37-53

[10] Pritchard, M. S. . “Teaching Engineering Ethics: A Case Study Approach.” In: *NSF DIR-882083* (1992), pp.245-263

[11] C E Harris, Davis M, Pritchard M S, et al. “Engineering Ethics: Concept and Cases”. (Third Edition and its translation version)

[12] Li ZF, Cong HQ, Wang Q, etc.. “Engineering Ethics”. *Tsinghua University Press*, (2016), pp. 130-131