

## **To Construct the Curriculum Effect Evaluation System of Engineering Ethics Education Based on the Kirkpatrick's Evaluation Model**

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## Abstract:

During the decades of continuous development of engineering ethics education, engineering ethics education has attracted more and more attention. Moreover, many colleges and universities around the world have set up various forms of engineering ethics courses. Engineering ethics courses need to be evaluated to see how effective they are. Timely and effective evaluation can not only test students' learning effect but also promote the improvement of engineering ethics curriculum. Therefore, it is necessary to try to construct the evaluation system of engineering ethics education curriculum effect. Kirkpatrick's four-level evaluation model is considered as the most widely used training effect evaluation model in the world. It has been more than 60 years since Donald L. Kirkpatrick at the University of Wisconsin proposed the model in 1959. This study's first and most important concern is the feasibility of applying the model in the interdisciplinary field. Whether the successful application of Kirkpatrick's model in enterprise training can also achieve good results in school education, especially in engineering ethics education, and how feasible it is. After analyzing the question from two aspects: (1) the relationship between education and training; (2) the goals of engineering ethics education and the logic of Kirkpatrick's evaluation model, this paper concludes that Kirkpatrick's evaluation model could be used for reference in engineering ethics education evaluation. Then, based on Kirkpatrick's evaluation model and the characteristics of engineering ethics education curriculum instruction, this study designs the evaluation system of engineering ethics education courses from a macroscopic perspective. The evaluation system is also divided into four levels: *Reaction Level*, *Learning Level*, *Behavior Level*, and *Result Level*. Finally, from the perspective of the concrete implementation of the system framework, the specific contents of the framework are further sorted out and summarized.

**Keywords:** Engineering Ethics Education, Engineering Ethics Curriculum Effect Evaluation, Kirkpatrick's Evaluation Model

## Introduction

During the decades of continuous development of engineering ethics education, more and more attention has been paid to engineering ethics education. Many universities around the world have set up various forms of engineering ethics courses. No matter what form of an engineering ethics course, its fundamental purpose is to complete the ethics education of engineering students by implementing the course to achieve the course objectives. From the perspective of the relationship between engineering activities and human beings and the significant influence of engineering on society, as the leaders of modern engineering activities, engineers' behavior will directly affect engineering itself, society, and the environment. More and more problems and dilemmas caused by engineering activities make society have higher and higher expectations of engineers, who are required to put human welfare first and have moral

sensitivity, moral awareness, responsibility, ethical judgment, and willpower. They must be able to perceive, understand and pay attention to various ethical issues in engineering activities and their possible consequences. This also directly points to the high quality of engineering ethics education requirements. Evaluation is the necessary way to test the effect of education and training. Previous research and practice have shown that the inadequate and poorly executed appraisal system may hinder training effectiveness [1]. The lack of awareness of or access to methods and tools for the evaluation process is another possible reason for inadequate evaluations [2]; however, the assessment process can be straightforward [3].

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 as '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 courses. 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 include. He believed that survey analysis can 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.

The above evaluation mainly focuses on evaluating students' academic performance in engineering ethics or aims at a particular time (classroom or after graduation). Although scientific evaluation results can be obtained, the effect of engineering ethics education cannot be fully evaluated under the continuity of talent training and the lag of engineering ethics practice. This also means more room for development in the systematic and comprehensive assessment. Therefore, from the perspective of the lasting influence of engineering activities and the process of engineering ethics education, this study believes that the evaluation of engineering ethics education should be based on coherent and systematic thinking and a comprehensive evaluation of engineering ethics education. This task is not easy, nor can it be created out of thin air. The Kirkpatrick's evaluation model is regarded as the world's most widely used

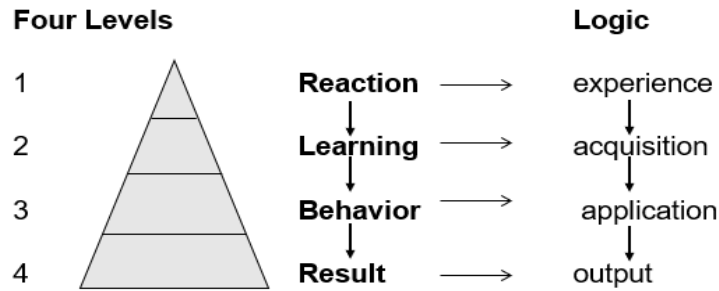
training effect evaluation model [9]. After decades of development, it has been widely used in training and education circles with remarkable effects. The four-level structure of Kirkpatrick's model can provide an excellent reference for systematic and whole-process evaluation. Given this, this study demonstrates the feasibility of the application of Kirkpatrick's model in the evaluation of engineering ethics education, and based on referring to Kirkpatrick's model and thoroughly combining the characteristics of engineering ethics education curriculum instruction, attempts to design the evaluation system of engineering ethics education curriculum from a macro perspective.

## **Methodology**

This paper uses literature research and comparative reference methods to construct the evaluation system of engineering ethics education based on the Kirkpatrick's evaluation model. First, this paper reviews the literature on the Kirkpatrick's evaluation model and its application in other fields. It fully demonstrates the feasibility of the Kirkpatrick's evaluation model in engineering ethics education. Then, by disassembling and drawing lessons from the model, the framework of the engineering ethics education evaluation system is constructed.

### ***Kirkpatrick's Evaluation Model***

Kirkpatrick's four-level evaluation model is the world's most widely used training effect evaluation model. This model was proposed in 1959 by Donald L. Kirkpatrick of the University of Wisconsin, so it is often referred to as the 'Kirkpatrick evaluation model' [10], [11]. In 1994, Kirkpatrick refined the model to make it more relevant to the times. Kirkpatrick's evaluation model includes four levels: *Reaction Level*, *Learning Level*, *Behavior Level*, and *Result Level*. The *Reaction level* mainly evaluates the students' reactions and feelings to the training and understands the students' satisfaction with the training, such as the student's impression of the course contents, teaching time and place, teachers' teaching skills, and teaching methods. The *Learning Level* mainly evaluates the learning effect of the students, that is, whether the students have improved in knowledge, skills, attitudes, and other aspects at the end of the training. The *Behavior Level* mainly evaluates the students' application and proficiency of learning contents, that is, whether the students can consciously apply the knowledge and skills learned in training after their changes in behavior (the change of behavior and learning habits to improve learning). The *Result Level* mainly evaluates the personal performance effect of trainees through training, that is, to understand the effect of departmental or organizational changes brought about by training. The logical framework of the model can be further summarized as "prior experience - achievement acquisition - achievement application - application effect", namely "experience - acquisition - application - output" (Figure 1). The Kirkpatrick's evaluation model increases the depth and difficulty of the evaluation layer by layer. Based on the diversified evaluation methods, the evaluation activities are carried out at different levels through extensive questionnaire surveys, interviews, observation, and other methods. This model opens up the precedent of training effect evaluation and lays a good foundation for the research of later scholars. It is the classic enterprise training effect evaluation model and has been applied to teacher training evaluation, teaching effect evaluation, higher education quality evaluation [12], [13], etc.



**Figure 1: Kirkpatrick's four-level evaluation model**

### ***The Adaptation of Kirkpatrick's Evaluation Model to the Engineering Ethics Education Setting***

Applying a model in the interdisciplinary field requires a complete analysis of its feasibility. Whether the successful application of the Kirkpatrick's model in the field of enterprise training can also achieve a good effect in the field of school education, especially the field of engineering ethics education involved in this study, and how feasible it is, we can analyze it from the following two aspects:

#### (1) The link between education and training

Education is a social activity to train people to pass on production experience and social experience to promote the growth of the next generation. In the narrow sense, education is the sublimation of individual spirit; education is, in essence, a nurturing activity. "Training" refers to the knowledge and skills imparting activities that the organization provides to employees to help them complete their work. Obviously, from the definition of "education" and "training", we can see that education in a broad sense includes training, and training can be regarded as a form of education. The definitions of education and training cross both contain the meaning of "cultivation"; The contents of both must be beneficial, benign and both need to be evaluated. Therefore, the evaluation model applicable to the training sector can also be used to reference the education sector. As a classic model of enterprise training, the Kirkpatrick's model also has some inspirations for constructing the classroom evaluation model.

Many authors have adapted the Kirkpatrick's model for use in academic contexts by determining metrics and assessments geared to specific learning environments, which shows the potential of its use in this area [14], [15]. Ruiz and Snoeck [16] explain that the Kirkpatrick's model applies to various types of educational programs and various national and multinational contexts. As Bewley and O'Neil [17] assert, the Kirkpatrick's model has been used for evaluation in many training and educational settings. Similarly, Heydari et al. [18] confirm that although all models have some deficiencies, the Kirkpatrick's model is suitable and has an acceptable performance record for assessing educational programs.

## (2) The objectives of engineering ethics education and the logic of Kirkpatrick's evaluation model

From the essence of education, engineering ethics education can also be regarded as a kind of training through the course of ethics training for students. By combing the literature on the objectives of engineering ethics education, the objectives of engineering ethics education are summarized as follows: enhance ethical awareness, sensitivity, and sense of responsibility (moral imagination, the identification of ethical problems and dilemmas, the understanding of ethical problems), increase the understanding and mastery of ethical norms and standard rules (the cognition of ethical norms, the application of ethical norms, professional value orientation, and cognition of responsibility), and improve ethical judgment and decision-making skills (solve problems and develop sound solutions through clear reasoning and consideration of all key stakeholders). The practical attribute of engineering and the goals of engineering ethics education determine that the knowledge and skills acquired by students through engineering ethics education will eventually be applied to practice. This is consistent with the logic framework of Kirkpatrick's evaluation model, which is “initial experience - achievement acquisition - achievement application - application effect” (“experience - acquisition - application - output”). Therefore, in evaluating engineering ethics education, we can learn from the model of Kirkpatrick's evaluation.

## Results and Discussions

Based on referring to the Kirkpatrick's evaluation model and thoroughly combining the characteristics of engineering ethics education curriculum instruction, this study designs the evaluation system of engineering ethics education curriculum from a macro perspective and scientifically constructs the curriculum effect evaluation framework.

### (1) *Reaction Level* Evaluation

In the Kirkpatrick's evaluation model, *Reaction Level* evaluation is the first level evaluation, mainly used to evaluate the trainees' satisfaction degree and preference degree of training. Kirkpatrick also called it “customer satisfaction evaluation”. In assessing the *Reaction Level* of engineering ethics education, we mainly understand the students' overall response and subjective feelings to the courses. The evaluation is mainly carried out from three dimensions: curriculum cognition, teaching implementation, and self-evaluation after class. The main contents include: students' understanding and interest of the curriculum; satisfaction with teachers, course content, course form, teaching method, teaching environment; and self-evaluation of course learning. At this level, a questionnaire survey is used to collect the primary information, which is supplemented by data collection, classroom observation, and interviews (Figure 2).

**Figure 2: Reaction Level Evaluation**

<b>Reaction Level</b>			
<b>first-level indicators</b>	<b>second-level indicators</b>	<b>evaluation contents</b>	<b>proposed evaluation methods</b>
curriculum cognition	students' understanding and interest of the course	<p><b>Students:</b></p> <ol style="list-style-type: none"> <li>1. Is engineering ethics education necessary?</li> <li>2. Why do you take such a course?</li> <li>3. Are you interested in this course?</li> <li>4. In what form should engineering ethics education courses be carried out?</li> <li>.....</li> </ol> <p><b>Teachers:</b></p> <ol style="list-style-type: none"> <li>1. Why do you open this course? (your rationale and idea about the course)</li> <li>2. What is the goals of the course?</li> <li>.....</li> </ol>	<ul style="list-style-type: none"> <li>·questionnaire survey</li> <li>·data collection</li> <li>·classroom observation</li> <li>·interview</li> <li>.....</li> </ul>
teaching implementation	students' satisfaction with teachers, course content, course form, teaching method, teaching environment	<p><b>Students:</b></p> <ol style="list-style-type: none"> <li>1. Is the teacher competent for the teaching of this class?</li> <li>2. Does the course contents meet your learning needs?</li> <li>3. Do you like the form of this course?</li> <li>4. Is the teaching method satisfactory?</li> <li>5. What problems have you encountered in the course study?</li> <li>6. What do you think needs to be improved in this course?</li> <li>.....</li> </ol> <p><b>Teachers:</b></p> <ol style="list-style-type: none"> <li>1. Are you competent for the teaching of this class?</li> <li>2. What problems do you encounter in teaching?</li> <li>3. What needs to be improved?</li> <li>.....</li> </ol>	
self-evaluation after class	self-evaluation of course learning	<p><b>Students:</b></p> <ol style="list-style-type: none"> <li>1. Does your interest in engineering ethics increase after taking this course?</li> <li>2. Do you think you have learned anything from this course?</li> <li>3. Do you think this course is helpful to improve personal awareness and ability of engineering ethics?</li> <li>.....</li> </ol>	

## (2) Learning Level Evaluation

*Learning Level* evaluation is used to evaluate the degree of change in knowledge, skills, and attitudes acquired by trainees through training. The growth of knowledge, the improvement of skills, and the change of attitude are the three means by which training programs can be realized. The assessment of the *Learning Level* of engineering ethics education mainly gets students' mastery of the curriculum knowledge and ethical norms. It should be noted here that the ability to analyze and solve ethical problems is mainly evaluated at the *Behavioral Level*. Therefore, the evaluation at this level is mainly carried out in the form of a questionnaire survey, supplemented by the results of the end-of-course examination as a reference (Figure 3).

**Figure 3: Learning Level Evaluation**

Learning Level			
first-level indicators	second-level indicators	evaluation contents	proposed evaluation methods
curriculum knowledge	basic knowledge of engineering ethics, ethical principles, risk, safety, responsibility and stakeholders .....	<b>Students:</b> 1. Please refer to the end-of-course examination questions 2. other exams ..... <b>Teachers:</b>	· questionnaire survey · the end-of-course examination .....
ethical norms	the understanding and mastering of engineering ethical norms	1. The proportion of these contents in the teaching plan and syllabus .....	

## (3) Behavior Level Evaluation

*Behavioral Level* evaluation refers to the degree to which trainees apply what they have learned in training to practical work and the behavioral changes brought to trainees. In applying training evaluation, many projects only go to the *Reaction* and *Learning* levels; the application of the *Behavior* and *Result* levels are often missing. As a result, the value of the training itself becomes smaller. In order to avoid this situation, this study decided to carry out this level of assessment in the form of simulated cases.

On the one hand, case teaching is a standard teaching method used in engineering ethics education. Scholars at home and abroad have also developed many real or virtual engineering ethics cases. On the other hand, many American scholars have developed several scales for evaluating engineering ethics education to evaluate students' engineering ethics ability. All these provide a reasonable basis for this level of evaluation. This level mainly corresponds to ethical awareness and ethical ability in



the goals of engineering ethics education. At this level, the evaluation is mainly carried out as an ethical evaluation scale. Cases involving ethical dilemmas are selected and graded according to the student's answers (Figure 4).

**Figure 4: Behavior Level Evaluation**

<b>Behavior Level</b>			
<b>first-level indicators</b>	<b>second-level indicators</b>	<b>evaluation contents</b>	<b>proposed evaluation methods</b>
the application of what students have learned	ethical problem identification, information analysis, interest balancing, multi-perspective analysis, solution to the problem.....	1. presented as 'scale & case 2. example: the Pittsburgh-mines Engineer Ethics Assessment Rubric, etc. .....	·an ethical evaluation scale ·simulated cases .....

(4) *Result Level* Evaluation

In the Kirkpatrick's evaluation model, the *Result Level* evaluation is mainly used to test whether the trainees apply the knowledge, skills, and attitudes they have learned into practice and bring results to the enterprise after the training. In an enterprise, outcome change includes tangible outcome change, such as productivity improvement, sales increase, quality improvement, personnel turnover reduction, cost reduction, and profit improvement, as well as intangible outcome change, such as customer satisfaction improvement and employee morale growth. When applied to higher education, the evaluation of the *Result Level* refers to the career success of graduates, the admission rate of higher level learning, the service society, the social reputation of colleges and universities, etc., which can be explicitly realized through the questionnaire of graduates, the evaluation of employing departments, the recognition degree of services, etc.

According to the definition of the *Result Level* in the Kirkpatrick's evaluation model, the evaluation of the *Result Level* of engineering ethics education should be expressed as examining the students' compliance with and practice of ethical rules and professional ethics in their work after graduation through the study of engineering ethics education courses in schools, and evaluating the solution of practical engineering problems in work and the impact of the engineer's role on individuals, units, and society. This is the highest level of the Kirkpatrick's evaluation model and the ultimate goal of all training and education work. For the following reasons, only evaluation methods at this level are described and prospected in this study. First of all, the importance of the evaluation at this level determines that the evaluation needs a long-term final investigation, and the evaluation cycle is long. The period of this study cannot cover the evaluation cycle required at this level. Second, undergraduate

engineering ethics education in the country of this study is still in its initial stage. The engineer ethics curriculum system needs several years or more prolonged accumulation and development. This level of evaluation is more suitable to be carried out after the long-time development of engineering ethics education. Third, the difference between engineering ethics education and training in the Kirkpatrick's evaluation model is that, in training, it is clear whom to train, and it is easier to obtain the support of the training institution in the evaluation. However, the research shows that the employment of the students receiving engineering ethics education has yet to be discovered. Since engineering ethics education has yet to reach a consensus in society, with the development of engineering ethics education, relevant units need to gradually improve their understanding of engineering ethics education and then participate in engineering ethics education. Therefore, this study only attempts to propose a feasible way to evaluate the *Result Level* under mature conditions in the future(Figure 5).

**Figure 5: Result Level Evaluation**

<b>Result Level</b>			
<b>first-level indicators</b>	<b>second-level indicators</b>	<b>evaluation contents</b>	<b>proposed evaluation methods</b>
individual	individuals self-evaluate ethical performance at work.....	1. How do you comply with the ethics and professional codes in your work? 2. How many engineering ethical problems have you encountered in your work? 3. To what extent does the ethics education you received in school help you to solve the problems of engineering ethics in your work? .....	·sample survey ·follow-up investigation ·questionnaire survey ·data collection ·interview ·comparison .....
employer	the employer's evaluation of an employee's ethical performance	1. employer 2. colleagues .....	
society and the public	social evaluation of engineers in a certain field; statistical comparison of engineering accident incidence .....	1. social evaluation and reputation of engineers in various industries 2. the statistics of the incidence of engineering accidents in a certain period of time; selection and analysis .....	

## Conclusions

This study adapted the Kirkpatrick's evaluation model, which includes four levels of training outcomes, to construct the Curriculum Effect Evaluation System of Engineering Ethics Education. Based on the feasibility analysis of the Kirkpatrick's model and its application in engineering ethics education, the framework constructed in this paper could provide a preliminary framework for the sustainable improvement of the curriculum and the learning effect of students, offering a macroscopic reference and inspiration. Although this framework system does not contain specific courses and tools, it provides framework and system support for assessment implementers to a large extent by constructing first-level and second-level indicators based on four evaluation levels, listing specific assessment contents under indicators, and giving corresponding assessment method suggestions. At the same time, the framework offers the assessment implementer the space to assess according to the specific curriculum. Therefore, in the curriculum effect evaluation of engineering ethics, we must pay attention to specific details to carry out targeted, practical, and operational course evaluation. The following is a further review and summary of the specific contents of the framework of the evaluation system of engineering ethics education constructed in this study from the perspective of the concrete implementation of the framework.

The standard and operable index systems should be constructed at all levels. The evaluation indicators should be set with clear definitions and standardized language so that the evaluation implementer can correctly understand their meanings, avoid the phenomenon of crossover or repetition of indicators, and prevent the implementer from having ambiguous meanings of indicators. In addition, when the evaluation index system is used for evaluation, the evaluation implementer can assign a quantitative value to each index according to the specific situation of the course taught. In this way, the specific situation can be handled flexibly, and the teaching situation of the course can be intuitively understood.

The evaluation indexes and methods should be selected according to the curriculum objectives. In the construction process of evaluation contents and evaluation system, it is necessary to consider whether indicators are easy to obtain fully. Evaluators must know how to judge and give opinions based on fundamental indicators and evaluation contents. Establishing the evaluation index system should comprehensively reflect the various dimensions of the course effect of engineering ethics education. According to the training objectives and talent training needs of engineering ethics education, the main indexes and evaluation contents that reflect the teaching effect of engineering ethics should be found out as comprehensively as possible. The selected indexes and evaluation contents can well reflect the sub-objectives with strong representativeness and comprehensiveness. The evaluation index is comprehensive, complete, and systematic.

The multi-objectives of engineering ethics course make the realization of its multiple objectives needs to be realized through the continuous efforts of many courses from general education to professional education. The interdisciplinary nature of engineering ethics education makes it impossible to achieve its educational objectives only by opening one course. Therefore, we should select the evaluation indexes and methods according to the course objectives when evaluating a particular engineering ethics course based on the model. At the same time, when dealing with the relationship between the introductory courses and the subsequent courses, the evaluation situation and results of the preparatory courses will be fed back to the later courses so that the teacher in the later courses can make corresponding adjustments and improvements.

Pay attention to the timeliness and feedback of evaluation results. Most of the evaluation of the effect of engineering ethics courses is carried out after the implementation. Although the evaluation can understand students' feelings about the course, it cannot observe the more significant changes in students before and after implementing the model. Therefore, it is suggested to conduct questionnaires and interviews with teachers and students before class to understand their pre-class learning style, learning expectation, and learning attitude to provide control samples for later evaluation. At the same time, because of the evaluation characteristics of the *Reaction Level, Learning Level, Behavior Level, and Result Level*, reasonable and adequate time should be selected to timely evaluate the object in order to ensure effective and accurate evaluation results.

Another purpose of the evaluation is to improve the teaching of the course. Therefore, the evaluation results of the course should be summarized in time to provide a reference for targeted improvement and valuable information for the subsequent arrangement and implementation of engineering ethics courses to promote the high-quality development of education.

The participation of multiple subjects in the evaluation should be strengthened. We should emphasize the diversity of evaluation participants. Diversified evaluation subjects can effectively avoid the one-sidedness and bias of evaluation and improve the authenticity and effectiveness of evaluation conclusions. The evaluation subject of the teaching effect of engineering ethics should include students, peers, teachers, other groups, students' employers, the public, and other stakeholders.

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