

Evaluation of Learning Effect of CDIO Education Model Based on Bayesian Network

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Abstract: The CDIO syllabus expresses the engineering basic knowledge, personal ability, interpersonal team ability and the whole process ability of CDIO that engineers must have in a step-by-step way. The CDIO capability index is not only the training goal of every major in the university, but also test index to evaluate the effect of students' training. According to working practice of TOPCARES-CDIO education model in university, the author puts forward to evaluate the students' ability index according to the students' curriculum/project achievement, and establishes the model by using Bayesian network, describing the relationship between teachers' rating of students' ability indexes and employer's rating on students' work ability. The model can be used to predict the degree to which the students in university meet the needs of the employer's work. Based on this, the model can also make students know how to carry out the further study and make the teacher know the whole situation of their teaching objects so as to adjust the teaching plan, teaching content and even the professional training plan.

1. Introduction

CDIO engineering education model is a kind of higher engineering education model co-founded by MIT[1], Swedish Royal Institute of Technology and other universities with several years of research, exploration and practice. CDIO represents conceptualization of (conceive), design of (design), implementation of (implement) and operation of (operate). CDIO educational models are educational ideas and carriers based on the conception, design, implementation, and operational life cycle of real-world products and systems. Based on CDIO syllabus and standards, students can acquire engineering ability in an active, practical and organic way. Engineering capabilities include individual scientific and technical knowledge, lifelong learning, communication and teamwork skills, as well as the ability to build products and systems in social and corporate environments. Today's information technology makes access to information extremely simply and fast. Therefore, for engineers, they not only acquire information, but also should acquire a kind of understanding of the relationship between information and learn how to obtain it. They can apply and correlate information to synthesize new information and solve practical problems.

CDIO includes three core documents: a vision, an outline, and 12 standards[2]. CDIO wants to provide students with an engineering education that emphasizes engineering-based, the design of real-world products and the design-implementation-run (CDIO) process of systems[3]. Its outline, for the first time, presents the engineering fundamentals, personal skills, interpersonal team skills, and overall CDIO process capabilities that engineers must possess in a step-by-step, detailed way (level 3, 70 items, more than 400 items) so that the reform of engineering education has a more clear direction and systematization. Its 12 standards give systematic and comprehensive guidance to the implementation and inspection of the whole model[4], which makes the reform of engineering education concrete, operational, measurable, and has important guiding significance for both students and teachers. CDIO embodies the unity of systematization, science and advancement, and represents the development trend of contemporary engineering education.

The ability index of CDIO is not only the training target of the students of every major, but also

the test index to evaluate the effect of the training of the students. According to working practice of TOPCARES-CDIO education model in school, the author puts forward to evaluate the students' ability index according to the students' curriculum / project achievement, establishes the model by using Bayesian network and describes the relationship between the teacher's rating of students' ability and the employer's rating on students' work ability. Meanwhile, the author predicts the degree to which the students in school meet the needs of the employer's work by using this model, and more objectively evaluates the learning effect of CDIO education model.

2. Practice Of OBE-Oriented Training And Evaluation Of CDIO Talents

2.1 Establish the Goal of Professional Training.

The author's university is based on the social demand, and applies OBE (Outcome Based Education) to orient TOPCARES-CDIO education model. Each letter of "TOPCARES" represents a kind of ability that a student should have, in which T(Technical Knowledge and Reasoning) refers to technical knowledge and reasoning ability; O (Open Minded and Innovation) refers to open thinking and innovation; P (Personal and Professional Skills) refers to individual professional ability; C (Communication and Teamwork) refers to the ability of communication, expression and teamwork; A (Attitude and Manner) refers to attitude and habit; R (Responsibility) refers to responsibility; E (Ethical Values) refers to values; S (Social Contribution by Application Practice) refers to the contribution of practical conception, design, realization and operation to society. Therefore, "TOPCARES" is the goal of training talents in schools, but also the ability indicators to test the training of talents. Each discipline will refer to the national relevant education standards and norms, and refer to the international standards. Through the investigation of various employers and the investigation of the relevant professional personnel training programs at home and abroad, we can determine that the specific capacity index of each discipline cultivates. Taking the major of engineering management as an example, the specific "TOPCARES-CDIO" ability index of this major is determined as the standard of cultivating students in this major, including 8 level 1 ability indexes, 31 level 2 abilities indexes and 55 level 3 abilities indexes.

2.2 Establish Curriculum / Practice Project Training Objectives.

Students acquire knowledge and abilities through curriculum learning and project practice during university. So in order to make the students trained in the major achieve the goal of professional training, it is necessary to break down the training objectives of the major into the courses and practical projects that are set up by the major, and students gradually acquire the knowledge and abilities set by the curriculum in the course of their study. The knowledge and ability accumulated by students through orderly curriculum study and project practice should be in line with the training objectives set by the major. The curriculum objectives of the CDIO model extend the traditional learning effects and clearly point out the abilities that individuals should possess through learning. These abilities reflect the requirements of the industry and the academic. The goal of a course (or practical project) not only includes imparting technology and knowledge to students, but also developing students' personal abilities, interpersonal skills, habits, etc.

Taking a course of engineering management as an example, under the guidance of specialized teaching objectives, the teaching objectives of the course are set from three aspects: theoretical knowledge, personal quality and professional skills. These include:

- (1) In the aspect of professional knowledge, students should master the foundation of software engineering quality management, the methods, techniques and skills of software engineering quality management.

- (2) In terms of "finding problems and expressing problems", students should be able to write reports according to the problems found in the process of quality assurance and quality control, to analyze the results and express them in a suitable way.

- (3) In the aspect of "solutions and suggestions", students should be able to put forward positive solutions and suggestions to the problems that are found in the process of software quality assurance

and quality control.

(4) In terms of the basic specifications of the industry, the students should be able to master the software engineering quality standard, and use the standard guidance of ISO9001, CMM, etc., and cut out the working standard suitable for practical work.

(5) In the aspect of “learning attitude and habit”, students should be able to cultivate good learning attitude and habit in the course of learning.

(6) In the aspect of seeking truth from facts, the students should be able to respect the facts of the product and the production process in the process of project quality planning, guarantee and control, and be trained the spirit of seeking truth from facts.

(7) In the aspect of “professional ethics, integrity and responsibility”, students should be able to perform their duties and have good professional ethics to the undertaken work of project quality management.

Each course / practice project in the profession has such a training objective, and in order to ensure that the professional training objectives are clear and completely broken down into the curriculum, we can use the “Professional goals-Curriculum goal Mapping Table” to describe the correspondence between different courses and different professional goals. We can also define the degree of contribution of each course to the goals.

2.3 The Assumption of the Evaluation of the Learning Effect in the CDIO Education.

During the course / project learning process, the teacher carries out formative examination (answering questions, exercises, assignments, unit items, curriculum items, etc.) and final examination (final exam, etc.) to get the grades of students in order to evaluate the students’ learning results. These grades are given on the basis of the knowledge, skills and qualities of the student, that is, students’ individual course / project scores can be broken down into curriculum / project goals. That is to say, to assess whether the course / project goals are achieved according to the students’ curriculum / project achievement; Because of the corresponding relationship between “course / project-ability” and “specialty-ability” mentioned above, the grades of students’ ability index set by each major can be evaluated by the grades of all courses / projects of students.

Although this assessment process is logical, whether the university’s evaluation of a student is consistent with the employer’s assessment is needed to be tested in practice. After all, the training of talents in the university meets the needs of the society. Students’ level of personal knowledge and ability are supposed to meet the needs of employers is our ultimate goal. The evaluation data of employing units can be derived from the evaluation results of students in the fourth year of enterprise practice, and also from the evaluation of graduates by employers after the employment of students. If the evaluation of employing unit is consistent with the course grades (knowledge and ability evaluation) of the students in university, the evaluation system of the university can be considered to be reasonable. Therefore, the author puts forward using the Bayesian network to set up a model, collecting the enterprise evaluation results of the students in the practice or employment, and the performance indexes of the students during the university to train the Bayesian network model. The model can not only describe the relationship between teachers’ evaluation of students’ abilities and the evaluation of students by employers, but also predict whether the students trained by majors can meet the needs of employers. Then we can re-examine the rationality of the goal of professional competence training.

3. Bayesian Learning Network Of Effectiveness Evaluation Model

3.1 Bayesian Network Theory.

Bayesian Network is a graphical model combining graph theory and probability theory. It is a directed acyclic graph (DAG) [5], with local and distributed learning mechanism and a graphical model representation based on probabilistic reasoning. It is able to make effective reasoning of incomplete, inaccurate, or uncertain information. The nodes of Bayesian networks represent the random variables of the problem domain and the directed edges represent the dependence between

nodes. Bayesian networks can be defined as follows:

Bayesian network is a graph theory model based on the probability relationship between random variables[6], which can be expressed as a triple (E, N, P) [7].

“N” is a set of nodes, $N=\{x_1, x_2, x_3, \dots, x_n\}$, each x represents a node, and the node variable can be an abstraction of any problem, such as a test value, an observation phenomenon, an opinion request, and so on. E is a set of directed edges, $E=\{x_i/x_j\} (x_i \neq x_j, x_i, x_j \in N)$. P is a set of conditional probabilities[9], each having a conditional probability distribution $P(x_i | \text{parents}(x_i))$, which reflects the intensity of association between nodes quantitatively.

Bayesian network is a process in which the probability of occurrence of target nodes is calculated by prior probability under the condition of determining the network structure. There are two common forms of reasoning[9]:

(1) Cause and effect reasoning. On the basis of knowing a certain reason, the probability of the occurrence of the result under the reason is calculated by the inference.

(2) Diagnostic reasoning. Some results have been known to occur, and the reason for obtaining the result and the probability of the occurrence are calculated by the inference.

3.2 The Establishment of the Evaluation Model of Learning Effect in the Mode of CDIO Education.

During the course / project learning process, the teacher assesses the student's learning performance and achievement, gives the course / project scores, and also scores the student's CDIO competency indicators. When all the courses break the scores down to the students' competency indicators, they can be rated against the students' competency indicators. For example, there are 31 secondary CDIO ability indexes of engineering management major. These items are the goal of cultivating students when making professional training plan. We hope that all the ability indexes of engineering management major can meet the minimum requirements of major when they graduate. These students' ability indexes represent the level of students' different abilities after four years of study, and the students' working abilities are also rated by their organizations after they enter the enterprise practice or work. Under normal circumstances, the university's evaluation of students should be consistent with that of the enterprise, but whether it is true or not, or whether the CDIO competency indicators set in the university are really concerned by the employer. As well as these training goals, which indicators enterprises pay more attention to, are all needed to speak with data. Based on these analyses, the author proposes a learning effect evaluation model system based on CDIO education model shown in figure 1. The Bayesian network model was trained by using the data of each ability index of students' CDIO and the data of enterprise's work level rating of students. The relationship between the rating of university ability index and the rating of students by employing units is established.

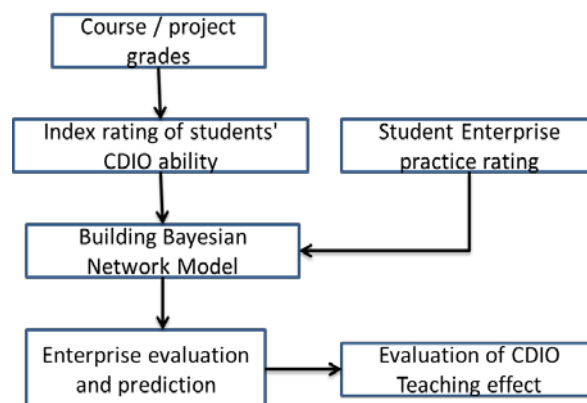


Fig. 1 schematic diagram of learning effect evaluation model system

After the establishment of Bayesian network, the future working ability of the students can be predicted, and the ability reflects the CDIO teaching effect of the university. Then the CDIO teaching effect of the university can be evaluated.

In the process of building Bayesian network, the input data is processed into discrete values. Therefore, the score of CDIO ability of students is divided into five grades: excellent, good, middle, pass and fail, and the rating scores of enterprises are treated by the same way.

4. An Experiment On Evaluation Of Learning Effect In CDIO Education Model

4.1 Bayesian Network Establishment.

The experiment data uses 300 data from the engineering management major, including the student CDIO capability index rating data given by teachers and the student's working ability rating data from the practice and employment unit.

The evaluation results of CDIO ability index are given according to the secondary competence index of TOPCARES-CDIO, which include 31 items totally: "1.1 Humanities and Social Sciences knowledge", "1.2 Mathematics and Natural Science knowledge", "1.3 Specialty basic knowledge", and "3.4 time and resource management capacity", etc. The predicted value is the rating data from the enterprise about the student's working ability, which is "Enterprise Assessment".

The model obtained by using 70% experimental data as training data shows that there is a correlation between the rating of engineering management professional ability and the rating of enterprise's working ability, but the strength of relationship between them is different. When the strength of this relationship is changing, the top 10 TOPCARES-CDIO competency indicators, which are most closely related to the performance rating of the enterprise are obtained. The specific data are shown in Table 1 (the data in the table are arranged in the order of TOPCARES-CDIO secondary coding and do not reflect the strong or weak order of the correlation between the professional competence evaluation grade and the enterprise work ability evaluation grade).

Table I 10 CDIO competency indicators most relevant

<i>Number</i>	<i>Secondary capacity Index coding</i>	<i>Secondary capability index</i>	<i>Level 1 capacity indicators</i>
1	1.3	Professional basic knowledge	Technical knowledge and reasoning ability
2	1.4	Professional knowledge	Technical knowledge and reasoning ability
3	2.1	Systematic thinking	Open thinking and Innovation
4	2.3	Creative thinking	Open thinking and Innovation
5	3.1	Ability to reason and solve problems	Personal professional ability
6	3.3	Information processing capability	Personal professional ability
7	4.1	communicative competence	Communication, expression, teamwork.
8	4.3	Team work	Communication, expression, teamwork.
9	5.2	Professional attitudes and habits	Attitude and habit
10	6.3	A sense of responsibility for the profession	Responsibility

4.2 Model Accuracy Evaluation

Using 30% of the experimental data as the test data, The prediction accuracy of "pass" for enterprises is as high as 92%; the prediction accuracy rate of "good" is 67%; the accuracy of

“excellent” is 82%; and the accuracy of “medium” is 76%. Only the prediction rate of “failing” is very low, and in this case, the data selected are the scores of trainee students or employed graduates who have been retained by the enterprise. The number of people rated as failing by the enterprise is very small. The data is not representative, so the accuracy is also low, and the total sample of this experiment is not many. With the increase of the number of graduates, the overall sample size becomes larger, and the accuracy of Bayesian network learning effect evaluation model will be greatly improved.

5. Summary

In this paper, a learning effect evaluation model based on Bayesian network in CDIO education mode is established to describe the relationship between the evaluation of students' ability indexes from their teacher and the evaluation of students by employers after students enter the society. This model can be used to predict whether the students trained in CDIO education model can meet the needs of employers. According to this, students can know how to carry out further study, and teachers can know the whole situation of their teaching objects so as to adjust teachers' teaching plan, teaching contents, teaching methods and even teaching objectives in a timely manner. At the same time, with changing the input data of the model, the model can also be used to describe what kind of students enterprises are more willing to enroll.

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