Math model of effectiveness of quality engineering education

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Abstract: The evaluation of effectiveness of education of quality engineering is one of the important issues of organization with special consideration by developing quality issues and ISO standards. Practically, the managers are always faced with the main problem of evaluating the effectiveness of these instructions. The existing models couldn't meet the demands of the managers of industries or engineers. In this study, by considering the existing shortcomings in the models of education effectiveness evaluation, we determine the indices of engineering education effectiveness and their weights and a model were extracted.
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1. Introduction

The superiority of importance of human resources among other organization resources is evident. Here, the development and educating the engineers as future process improved the abilities, capabilities, increasing knowledge and information, changing attitude of various industries and staffs. Some people know the efficiency of an industry depending upon the ability in determining and meeting the educational demands of engineers and staffs. Beside these emphases, the education at service of human resources and evaluating its effectiveness were considered mostly by managers and researchers. Quality models are formulated as the answer to these activities. If we don't say there is not quantity model evaluating the effectiveness of staffs' education, we can say that rarely a model is found that by this acceptance, this issue is considered. The managers are helped for management of staffs' education.

In measuring the education effectiveness in industrial organizations there are many difficulties, shortcomings and deficiencies. The most important shortcomings are:

- After performing the education, we can not state the effect of education in the form of a number and quantity.
- We can not determine the effectiveness of the effective factors on education.
- By various existing models of education effectiveness, the managers are not able to explain the quantity of the effect of the education presented and the organization objectives.

Education effectiveness

Effectiveness word is an important and complex concept. 2 centuries are passed of using productivity word [2]. Various definitions and views are presented by scientists about this term and its special synonyms, its efficiency. Sink and Tuttle in simple terms, defined efficiency "Doing things right", and effectiveness "doing right things" [2]. It should be said that various definitions are presented of these concepts and they are the basis of planning and calculations. The concepts in which education effectiveness are seen are:

- Determining the fulfillment of education goals
- Determining the observed results of students in educations performed
- Determining the consistency of the behavior of students with the expectations of their organization role
- Determining doing the right things as the goal of education
- Determining the ability created due to education to achieve the goals
- Determining the education added-value
- Determining the improvement of business success indices [3]

Indeed, we can summarize these concepts in "education effects".

A view of education effectiveness evaluation models

Normally, there are various approaches for education evaluation in many resources. In process view, the effective variables are arranged in a process and consecutively and the effectiveness is the result of the first issue as entries of second issue on second issue, the results of second issue as entries of third issue on third issue, etc. Thus, the investigation of

effectiveness was considered as a part of last step in the process. In all the classifications and models, the constituent elements identified the education process but their effecting method was not adjusted well.

In hierarchy view, such process is not observed. The effective variables on effectiveness are adjusted as a hierarchy of the variables and it is believed that each layer of hierarchy formed the upper layer. In these models after the evaluation of effectiveness, improvement measurements are done with the aim of improving and increasing the effectiveness on the required variable. Indeed, the variable is not identified or its effectiveness is not distinguished of other variables accurately.

In review of literature of this study, the following models were used to identify the education effectiveness indices:

SIP model [4], validity model[4], social test model [5],CBT model [1], C.A.P.O model [1], education investigation model, intervention[6], location, intervention, effect and value modle[7], Salivan evaluation model, Tyler evaluation model[6], Crack Patrik model[8], capital return model, Juran view [20]

The researchers by investigating the above models and the critics on education effectiveness evaluation models formulated a new model. The critics considered by the researches are:

What is done in the form of effectiveness evaluation methods of engineering education, is mostly survey or effect evaluation. Indeed, what is evaluated, is the view of learners and participants in education and this definition is far from education goals and education goals are ignored.

In most of the existing models, the result of the evaluation of effectiveness of at service educations cannot be stated in the form of a number and quantity.

The amount and share of effectiveness of various indices of at service education are unknown. The previous descriptive models described the indices and don't show the importance and weight of indices.

The education goals are emphasized at the beginning of education process but in the final step of education process, the evaluation of education effectiveness is used and nothing is said about the effects of education.

2. Methods

This study was applied in terms of objective. As the results are given to the operation managers and help them in guiding and managing the organization.

Research stages

Modeling stage

In the first stage, the researcher modeled effectiveness evaluation. The designed model in this stage is an interpretation of descriptive models formulated by other researchers beside the raw views of the researchers with their required model and was raised as initial proposed model. The initial model by the view of "Experts group" was evaluated, modified and renewed and the expected model was extracted. Thus, this stage of the study was survey.

In terms of operation, the researchers in this stage at first investigated various models of education effectiveness and extraction of important indices. Based on this fact, at first the researchers were succeeding to extract about 190 education effectiveness evaluation index. By initial investigation and receiving the view of experts and integrating the synonym indices, this index was reduced to 110 being classified in four groups. The first three sections of this classification were the main and classic sections being emphasized as education process by education pioneers. By the critics of these models, the fourth section was added to this classification. Thus, the required education process is defined as the followings:

1- Need assessment and education planning, 2- Performing education programs, 3- Education evaluation, 4- The effects of education of each of the classifications were divided into macro groups that finally all 110 extracted indices are placed in them and their classification is observed in columns (2) to (5) in Table 1.

Weighting the indices

In the second step, to extract the weight of indices, a questionnaire consisting of 625 questions were provided and distributed among the experts. The reason of high number of questions in the questionnaire was the main pre-requirements of the researchers in this study and the assumptions are:

Education effectiveness is a collective phenomenon. It means that by staring education process, effectiveness is formed and by proceeding in its various stages, the education effectiveness was added to be completed.

If no stage of education process is done, the education effectiveness is zero and if all the education steps are done completely, the effectiveness is 100 (or complete).

Extraction indices affect each other and themselves. It is required that the presented questionnaire can receive the views of experts by considering these characteristics. The questionnaire was provided in two stages. In the first stage, the initial questionnaire was provided based on review of literature studies and researcher-built model and was

given to a group of experts. By asking the views of experts on this questionnaire, it was completed and the final questionnaire was prepared.

Study population, sampling method and sample size

The study population were all the experts of teaching quality in Iran industries being selected based on two main factors of specialization (in organization education and quality engineering education) and access.

The data analysis instruments

The data of questionnaire were analyzed after extraction in the following stages:

a. Weighting the micro indices

To calculate the micro indices weights, the following stages were considered:

1- Paired comparison of micro indices- in this stage by "the least weighted sum square" the micro indices were weighted. In this stage, 110 micro indices extracted of 26 main index groups, in 5671 paired comparison were weighted. In this weighting, the judgments as paired were made in separated matrices of main indices with compact scale.

2- No-scale- As the paired comparisons had semantic load in accordance with its importance, we can not do any calculation or comparison on them. In the next step, we considered the no-scale of paired comparisons matrix.

3- Rows average- The last step to calculate the weights of micro indices is the calculation of the average of each row of no-scale matrix that gives the weight of each index.

b. The weight of main indices.

To calculate the weights of main indices, Dimatel technique 1 was applied. This technique can divide the components and elements (variables and components) of an assumed system to two separate sets of cause and effect and show the causative relations between them [10].

The first step in Dimetal technique is such that constituent elements of the system can be extracted with initial causative relation between these components by the idea of experts. To do this, the results of questionnaire distributed among the experts were extracted. The medium of the answers of the statistical sample of this study to each question was extracted as matrix M.

In the next step, the non-scale matrix of matrix M was achieved of dividing all the elements of matrix M by the biggest row sum of this matrix and it is called M'. Then,

$$\hat{M} = M'(I - M')^{-1} \quad (1)$$

Should be calculated.

The final calculation of 26 indices was achieved of non-scale of matrix R+J. Where R is the matrix of sum of each matrix row $\hat{M}$ and I column sum of $\hat{M}$.

Descriptive model

The researchers based on the study of review of literature and following assumptions determined descriptive model of image 1:

- There is an unknown interaction between the indices and this interaction should be identified.
- Each of the indices had weight affecting the calculations of evaluating education effectiveness.
- It is expected that education effectiveness is calculated as hierarchy. It means that each index group defined the amount of head group and head groups determined the amount of each four main sections and finally it leads into the final calculation of effectiveness.
- Effectiveness can be collected. It means that if the value of all the indices is zero, its effectiveness is zero and if the indices are maximum, the final amount of effectiveness is maximum.
- For simplicity of the calculations and easy understanding of the effectiveness achieved amount, the maximum is equal to 100.

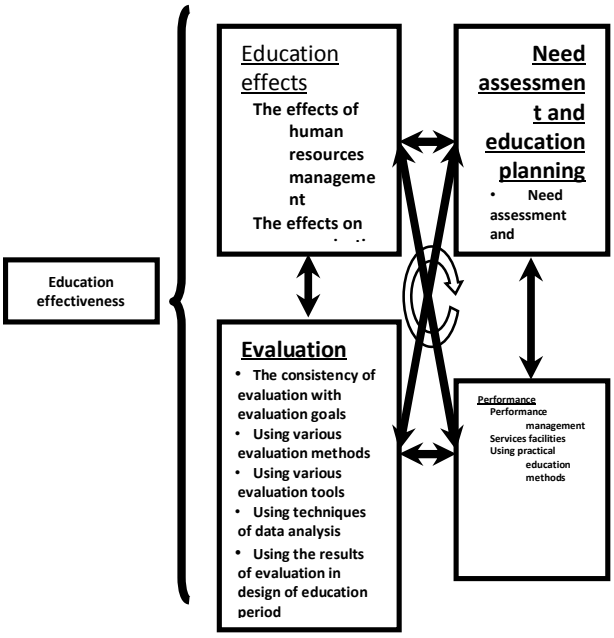

Image 1- Descriptive model of the study

Math modeling

Based on the study assumptions, it was required to investigate the behavior of education effectiveness function ranging zero to 100. At first, by two variable model analyses, it was assumed to identify effectiveness function behavior by one variable. In this case, the 5 behavior of image 2 was achieved.

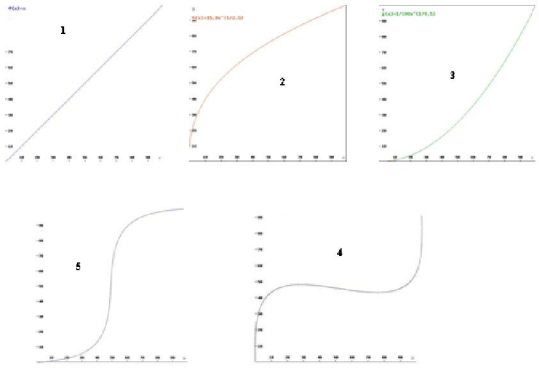

Image 2- Different kinds of predictable behaviors of effective education math function

If this one-variable function is turned into two-variable function, in 3-D space we can observe funnel curves as the following model:

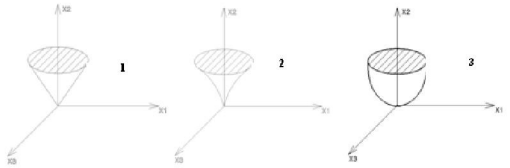

Image 3- The main samples of education effectiveness curve behavior in 3-D space

In a simplified state, two 2-D curves 4,5 and image 2 can be imagined in 3-D space, in accordance with two curves2, three images 3. By generalizing 3-D charts and their functions to three functions as bowl cone, funnel cone and simple cone (from right to left in image 3) we achieved:

(1) Simple cone

$$\frac{y^2}{a^2} = \sum_{i=1}^{110} \frac{x_i^2}{a^2}$$

$$y, x_i > 0$$

(2) Funnel cone

$$y = \frac{1}{2} a \ln\left(\sum_{i=1}^{110} x_i^2 \right)$$

$$y, x_i > 0$$

(3) Bowl cone

$$\frac{y}{c} = \sum_{i=1}^{110} \left(\frac{x_i^2}{a^2} \right)$$

$$y, x_i > 0$$

The researchers due to indefinite objective function and learning model, not imaging various solutions for the function and resources limitations as equalities and non-equalities couldn't use linear planning methods, neural network and genetics algorithm.

Model validity

By simulation of the mind of the experts of education effectiveness and quality engineering and comparing the effectiveness by them and extracted models, the models were validated. To do this, at first the experts were asked to state education effectiveness in various conditions of their mind. In these conditions, extracted math models were calculated. In other conditions, the experts were asked to determined the effectiveness by only variable and at the same conditions, the math models were performed.

Correlation of the achievement of simulation of the experts and math model were evaluated by accuracy 95%. This study showed that there is no correlation in bowl cone between the experts and the model. There is correlation between two other models and the view of experts and the correlation of funnel cone is more than simple cone.

3. Conclusion

In this study by knowing the weaknesses and critics of the common models of education effectiveness and the assumptions, we designed math model.

The extracted descriptive model has 4 main variables (Fig 1 and column 2, Table 1) divided into 26 main indices (column 3, Table1) and 110 macro indices (column 5, Table 1). By paired comparison technique and weighting of 110 micro indices were done (column 6, Table 1) and by dimatel technique, the weighing of 26 main indices were calculated (column 4, Table 1).

Math model of evaluating the engineering instructions was extracted as:

$$y = \frac{1}{2} a \ln\left(\sum_{i=1}^{110} x_i^2 \right)$$

$$y, x_i > 0$$

Table 1- The extracted indices and sub-indices with the identified weights

NO			Weight 4	Micro indices 5	Weight 6
1	Need assessment and education planning	Need assessment and identification of education needs	0,0421	Interview with future learners	0.0009
2				Interview with the supervisors of learners	0.0036
3				Interview with the inferior of learners	0.0010
4				Interview with the people who observe the behavior of learners	0.00018
5				Job analysis	0.0018
6				Interview with the previous teachers to review the periods	0.0012
7				Identifying SWOT (Weakness and strengths, opportunities and threats)	0.0030
8				Determining the ability of human resources to achieve the highest performance levels and performance gaps determination.	0.0090
9				The investigation of achieving the organization goals	0.0055
10				The investigation of the quality of services and productions	0.0035
11				Extraction strategy of education in line with key business needs.	0.0062
12				The investigation of the work quality by employee	0.0022
13		Need creation	0,0331	Receiving the views of experts and consultants about the future prediction of organization	0.0261
14	Need assessment and education planning	Human resources investigation	0, 0366	The investigation of people interested in education	0.0011
15				The investigation of people attending the education	0.0011
16				The investigation of people requiring education	0.0100
17				The investigation of required teachers	0.0033
18				The investigation of education staffs of organization	0.100
19				Determining the acceptance of learners	0.0033
20		Costs estimation	0,0398	Estimation of surcharge costs	0.0033
21				The estimation of education costs	0.0199
22				Estimation of other costs	0.0082
23		Determining goals	0,0462	The consistency of educational needs with general goals of quality of organization	0.0038
24				The clarity of education goals	0.0047
25				Determining the standards, levels, methods, different kinds, contents, criteria of education on education goals	0.0025
26				Stating educational behavior goals	0.0094
27				Selecting learning-teaching strategy in education	0.0101
28				Determine curriculum design	0.0025
29				Defining the evaluation goals	0.0034
30		The prediction of effective factors on performance	0,0298	The variety and number of education periods	0.0102
31				The identification and extraction of performance methods of education management	0.0052
32				The prediction of stages and problems of performing education periods	0.0027
33				Predicting and providing performance needs	0.0028
34				The prediction of schedule of periods	0.0026
35	Performance	Performance management	0,0405	Registering the events during the program	0.0017
36				Creating motivation in authorities of periods performance to participating in its improvement	0.0019
37				Supervising to observed determined education standards	0.0066
38				The consistency of practical and theory of education	0.0058
39		Giving services facilities	0,0379	The applied space and its equipments	0.0047
40				Education instruments and audio-visual equipments in education	0.0079
41				The quality and quantity of the feed presented	0.0016
42				The variety of the dishes available for the learner	0.0008
43		Using practical education methods	0,0447	The method of presenting the items	0.0025
44				The balance between theoretical and practical teaching	0.0076
45				The participation of learners during education program	0.0076
46	Evaluation	The consistency of evaluation with evaluation goals	0,0260	Giving feedback to improve the quality of evaluation system	0.0109
47				The evaluation of education presented based on determined goals	0.0036
48				The evaluation of education subject	0.0086
49				The evaluation of the education presented based on determined goals	0.0144
50		Using various methods of evaluation	0,0301	Using various evaluation methods	0.0099

51				Presenting the opportunity of filling evaluation form after education period to learners	0.0042
52				The comparison of education achievements by control and experiment group, the evaluation before and after education plan	0.0167
53				Evaluation after and before education	0.0127
54		Using various evaluation tools	0,0312	Using various measuring tools	0.0451
55	Evaluation	Using suitable techniques of data analysis	0,0286	Using suitable methods of data collection	0.0079
56				Determining suitable sampling methods and data collection	0.0067
57				The validity of collected data	0.0074
58				The existence of data collection tools	0.0067
59				Collecting data of the supervisors of learners	0.0020
60				Collecting data of inferior of learners	0.0029
61				Collecting data of people observing the behavior of learners	0.0029
62				Collecting data of learners	0.0016
63				Collecting data of top managers	0.0033
64		Using the results of evaluation in designing the education periods	0,0333	Using the results of evaluation in designing the education periods	0.0481
65	Evaluation	Using various resources for evaluation	0, 0341	The view of teachers about the consistency of the period with the needs of learners	0.079
66				The view of teachers about the consistency of the period with the needs of learners	0.0079
67				Forming supervising group on education	0.0089
68				The familiarity of supervision group on education with education evaluation mechanism	0.0098
69				The consideration of supervision group on education of standards	0.0098
70				The combination and distribution of supervising group on evaluation	0.0050
71		Evaluation of facilities region	0,0347	Evaluation of comfort (light, teacher voice, environmental noises, temperature, etc) of learner in education place	0.0418
72				Evaluating the services, evaluating the restaurant environment	0.084
73		The evaluation of financial zone	0,0402	Costs evaluation	0.0073
74				The calculation of capital return for each of education periods	0.0508
75		Evaluation of teaching zone	0, 0447	Evaluating the method of presenting the items	0.0147
76				The balance between theoretical and practical works	0.0188
77				Considering education goals as behavior during teaching	0.248
78				The evaluation of responding the questions of learner	0.0063
79		Teacher evaluation	0,0438	Evaluation of the teacher in terms of using curriculum	0.0079
80				The evaluation of teacher of communicating with the learner	0.104
81				The evaluation of teacher in terms of explaining the education issues	0.0096
82				The evaluation of teacher in terms of attraction of the class	0.0032
83				The evaluation of teacher in terms of scientific mastering of the subject of education	0.0148
84				Teacher preparation	0.0174
85		Evaluation of the satisfaction of learners	0, 0486	The satisfaction of learners at the end of education	0.0176
86				The satisfaction of learners after x weeks of education period	0.0527
87	Effectiveness	The effects of human resources management	0, 0410	The effect of new staffs education on working teams	0.0035
88				The effect of education in human relations	0.0043
89				The effect of education on reduction of staffs changes	0.0045
90				The effect of education on increasing the freedom of learners	0.0050
91				The effect of education on increase of salary of learners	0.0109
92				The effect of education on job improvement of learners	0.0040
93		The effects on organization goals	0,0414	The effect of education on achieving the mission- total goals of the organization and high performance	0.0272
94				The effect of education on education planning and improving human resources to achieve the organization goals	0.0055
95		Problem solving effects	0,0432	The effect of education on ability of identification and problem solving after finishing education period	0.0057
96				The effect of education on identification and problem solving in x weeks after education period	0.0282
97	Effectiveness	Productivity and quality effects	0,0416	The effect of education on improvement of quality	0.0120
98				The effect of education on improving quality	0.0120
99				The effect of education on reduction of the losses of educating new staffs	0.032
100				The effect of education on increasing the satisfaction of customer follow-up system	0.0056
101		Behavior effects	0,0489	The effect of education on improving the skill, attitudes of learners in the job	0.0179
102				The inclination to show the ability by using the skill in x weeks of education period	0.0106

103				The effect of education on improving the duties by learners	0.0032
104				The effect of education on commitment of learners on duty field	0.0069
105		Financial effects	0,0387	Capital return rate for each education period	0.0023
106				The evaluation of financial benefits of education	0.0038
107				The effect of educating new staffs on reduction of price of the goods	0.0018
108				The effect of education programs on company profit	0.0055
109				Increasing the sale of educating the sellers	0.0078
110				The effect of education on increasing production	0.0093

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