Statistical Investigation of a Successful Application Model of New Teaching Methods in Majors of Basic Sciences (Statistics and Mathematics) At the Bachelor Level

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Abstract
This research aimed to statistically investigate a successful application model of new teaching methods in the majors of basic sciences (statistics and mathematics).This is a mixed research (qualitative: alignment and quantitative-survey).Using a semi-structured interview with experts (university professors of mathematics and statistics), the effective indices on the optimal use of new teaching methods in the fields of statistics and mathematics were identified. Qualitative results showed that six indices, professor (scientific and personality characteristics), university (educational environment and infrastructure), course content, evaluation, students' critical-thinking skills, extracurricular activities in the correct and successful implementation of modern methods of teaching were effective. Then, based on these indices and their related categories, a researcher-made questionnaire with a Likert scale was distributed to the statistical population of professors (86 ones) using a simple random sampling method. Analysis of research data was done in statistical software. The results of Friedman tests showed that the content of the courses had the most importance and critical thinking skills had the least importance in the optimal implementation of new teaching methods in the fields of statistics and mathematics. Also, the results of Confirmatory Factor Analysis, CFA were presented to validate the proposed model.

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Introduction

Rapid changes in the form and manner of activity of educational centers are more than other organizations, and teachers' teaching is a major part of these activities.Teaching is a form of mutual activity between teacher and student with the aim of learning.This interaction becomes effective when both the teacher and the student influence the teacher's activity.In addition, this action can also be done indirectly (Mahmoudi Bard et al., 2017)."Questioning" is the most important effective factor in learning

(Ausubel, 1978); it is effective in expressing the basic skills needed by the students (Eggen & Kauchak, 2010) and increases student participation and more interaction with the teacher (Eggen & Kauchak, 2010;Satter Bull, Montgomery & Kimbal, 2002). It has the goals such as developing analytical (and abstract) thinking, strengthening students' motivation, etc.Question and answer with methods such as the development of critical thinking skills (Dewaelsche, 2015, Cojocariu & Butnaru, 2014, Popil, 2011, Javadi Mumtaz et al., 2015, Salehi et al., 2014, Badri Gregari and Khanleri, 2012, Ganji et al. , 2013), strengthening the level of understanding and correcting students' misunderstandings and creating a context for class discussion, strengthens the learning level (Lorsch & Ronkowski, 1982).The question and answer method increase the ability to analyze and organize information and self-confidence in students (Salehi et al., 2015).Baghaiee (2018) conducted a study with the aim of investigating the constructivist teaching model (E5) in teaching.In terms of classification, the constructivist method is among the active and exploratory methods that emphasize the production, control and generalization of knowledge.In the process of teaching, constructivism of the teacher and all facilities are facilitators and are considered among educational services.In this method, the student plays an essential role.The goal of actively searching of learners through various activities to discover solutions, concepts, principles and rules is one of the important goals in this method.Having an exploratory spirit to create questions, design, implement, invent and obtain answers is one of the characteristics of constructivism.Constructivism is one of the theories derived from the social-philosophical movement of postmodernism in the 20th century, which includes branches of psychology, mathematics, art, and education.The rapid growth and remarkable progress of science and human knowledge in recent years has made modern man in need of new educational methods and systems to expand awareness and keep up with modern science.To respond to this basic need, the theory of constructivism proposes a new point of view in the field of education, which seems to be a suitable alternative to the traditional system (Baghaiee, 2019).Rababi and Malazahi (2018) conducted a study with the aim of comparing modern teaching methods (active) and traditional teaching methods (passive).

Student learning in the classroom depends, among other factors, on the match between the students' preferred learning style and the teacher's teaching style.In the traditional method of school education, most of the class time is spent on the teacher's speech and watching and listening to the students.Students do assignments alone and are not encouraged to work in groups.On the contrary, in student-centered methods, the focus of activities is transferred from the teacher to the learner.In these methods, the responsibility of organizing what needs to be learned is left to the student.In active learning, students effectively engage in learning, ask and answer questions, and analyze the material.In the exploratory method, students' minds are encouraged to invent new rules and theories.In the innovation method, group solidarity among students increases their self-esteem and ability to solve problems (Arbabi and Malazahi, 2018).

Ashouri et al. (2018) conducted a study with the aim of investigating the effect of problem-solving teaching method on the mathematical creativity of sixth-grade male students in Sari city and found that the problem-solving teaching method is effective on sixth-grade male students' mathematical creativity.As a result, problem-oriented education will give students the opportunity to understand their problem well and analyze it by thinking about the problem and personal creativity and personally draw conclusions from them (Ashuri et al., 2019).

Asadi Khonki et al. (1400) presented a model of teaching based on constructivism for students.In the model of constructivism, they created meaning for various phenomena and

events from the perspective of their own experiences through exploration.Rashidi and Darvish Azghaneh (2013) showed that the implementation of the teaching model based on the concept of abilities (production of diverse ideas, new and innovative products), paying attention to the details related to the idea, accuracy, diagnosis, and judgment was effective.Hatami Shahpourabadi et al. (2017) presented six indices for effective teaching for college students.These six indices are mastery of the subject, presentation of new materials, eloquent and expressive expression, creating suitable contexts for participation, easy access to the teacher outside the classroom, intimate and friendly communication, punctuality, having a lesson plan and presenting it.In this research, eloquent expression and clear transfer and creating suitable fields for students' participation is of special importance in effective teaching.

Today, modern teaching methods consider the active presence of the student to be very effective in learning, and this presence is manifested when the teaching method is appropriate to the teaching of the courses for creating a change in the education process (Haghani et al., 2019). One of the effective methods in modern teaching is the problem-solving method, which is more widely used in the fields of statistics and mathematics than the other fields.Problem-solving is a creative method, especially when the problem is not well defined.Therefore, problem finding, idea generation and planning, which are elements of cognitive actions in creative thinking, are effective in all parts of problem solving (Maghami, 2004).

The teaching methods in universities, especially at the undergraduate level, are also the same as the teaching methods in the second secondary school, and the traditional teacher-student methods are still used.This issue is also seen more in the fields of statistics and mathematics, which have a purely theoretical aspect.Basic science fields such as mathematics and statistics, which are fundamental in many fields, but unfortunately, have not yet been applied well at the level of society.One of the important reasons for this challenge is the theoretical approach and type of teaching in these fields.

Despite the fact that many researches have been conducted in the field of teaching methods at the university level and lower educational grades (schools), but significant growth and progress in the implementation of new teaching methods at the university level have not been observed.Therefore, this research, relying on this point, attempts to discover and investigate a model of the optimal use of modern teaching methods that can be effective in the growth and flourishing of the capacities and abilities of bachelor level students in the majors of basic sciences, especially the theoretical majors of mathematics and statistics.

Therefore, the research question is as follows:"What are the effective indices on the desired teaching model (new teaching methods) in mathematics and statistics?".

Methodology

This is a mixed research in terms of practical objective (alignment and quantitative).In the qualitative part, 11 experts (academic professors of statistics and mathematics, faculty members) were selected using the purposive sampling method with theoretical saturation and the approach of selecting important people.The research question was provided to them in a semi-structured form.Qualitative validation was achieved using usability and reliability indices.Using interviews, basic categories and themes were extracted for the ideal model of implementing new teaching methods in the fields of statistics and mathematics, and finally the model was drawn.According to themes extracted in the interview section, a researcher-made questionnaire was compiled in order to evaluate and validate the ideal model of implementing new teaching methods and distributed to a wider community of university professors (86 people).The questionnaires were

analyzed by Cronbach's alpha and then the data were analyzed using SPSS and Lisrel statistical software.First, the normality of the data was confirmed, and then the descriptive statistics and finally the confirmatory factor analysis of the model were performed to confirm the validity of the model.In the last step, one-sample Student's t-test was performed for the status of indices affecting the desired (proposed) model.Friedman's (rank) test was also performed to determine the position of the mentioned indices in the model.In other words, it was indicated how much index (1) or (2) are effective in the model and which index has the most importance and influence in the proposed model.

Findings

As mentioned before, 11 people were selected for the semi-structured interview, all of whom were faculty members of statistics and mathematics departments.A semi-structured interview was used to answer the research question. The first step in data analysis was creating primary codes and text statements. Integration, combination and deletion of text statements from the interviews formed the basic themes, based on which, 30 basic themes were formed based on the first question of the research.

In Table 1, an example of basic themes is presented.

Table 1. An example of extraction of basic themes

Basic themes	Text statements
Professor (scientific, personality traits)	Expert 1: Effective teaching in the field of statistics and mathematics requires that the professor has sufficient knowledge and skills in the topics of the courses presented in the semester,also, has sufficient mastery in presenting content. Expert 2: The teacher, while having sufficient knowledge and skills to present the material, should try to present the material in one third of the class time and present the rest of the class time in the form of questions and answers or problem-solving methods or brainstorming. In general, in two thirds of the class time, there should be collaborative teaching centered on problem solving. Expert 3: The professor must update himself/herself once in a while (necessarily once a semester) with current scientific issues in the specialized field and the course presented in the semester. Expert 4: The teacher should be equipped with the best and most optimal teaching methods every once in a while.
Extracurricular and collaborative activities	Expert 1: One of the goals of extracurricular activities should be in line with students' participation in course topics. Expert 2: Unfortunately, despite many changes and developments in the educational system and curriculum content, the teaching method is still columnar, that is, only the professor is a lecturer. In most universities, like during high school and elementary school, the lecture method is still used, and the brainstorming method and other methods that make students participate in discussions are not implemented.Therefore, one of the goals of curriculum development should be to force and stimulate students to

	group work and their participation in problem solving and scientific discussions. This issue can be highlighted in extracurricular activities. Expert 3: In extracurricular classes, topics outside of the main curriculum should not be taught. Expert 4: The content of the extracurricular class activities should be in line with completing and opening the lesson topics in the main program. Expert 5: Some topics of the lesson should be expressed in the form of practical examples and models. Expert 6: Expanding scientific associations, scientific publications and holding internal workshops - university that will help improve the research.
Content and headings of statistics and mathematics courses	Expert 1: Some of the contents of the presented course materials and topics are very complex and very theoretical, and the majority of students have difficulty understanding them,or some contents are beyond the abilities and capacities of undergraduate students, but simply because there are lessons in the chapters, they are presented and evaluated by the professor. Expert 2: It is necessary to control and evaluate the effectiveness of educational aids such as textbooks common in the education market and to prevent the introduction of books that do not have effective content or to change their content. Expert 3: Some educational materials, such as educational writing supplies should be evaluated in order to have the most suitable and optimal writing materials for education.
The skill of interpretation and explanation-argument-combination	Expert 1: Accepting a correct and unique solution and answer causes students to lose the ability to interpret and explain scientific topics and solve problems. Expert 2: In extracurricular activities, it is possible to highlight the ability to explain and bring new reasoning to solve problems for the growth of students' academic performance. Expert 3: Due to the diversity of thinking and creativity in the new generation, therefore, in the preparation of lesson topics, the skill of composition and creation should be included according to the scientific needs of the new generation so that one can easily find and discover the superior horizons ahead. Expert 4: Curriculum goals should be based on fostering and strengthening thinking and creativity so that one can innovate in solving curricular problems. Expert 5: A lesson unit under the title of thinking and research methods related to each discipline should be included in the curriculum, so that students can get acquainted with research and development methods, create innovation and strengthen thinking and creativity, and be able to generate ideas.

	Expert 6: It is important to pay attention to the skill of creation in class topics. The topics that are shared by the professor in the class for participation should be such that the students' discussion about the presented material strengthens the sense of curiosity and thinking.
assessment	Expert 1: Although the evaluation method in the new educational system is slightly different from the old system, in both systems, data and bases related to the academic progress and academic performance of students have been considered. Tools related to performance evaluation should be up-to-date so that students can be evaluated optimally. Expert 2: Class assessment, exam, conference, class seminars and research should be done before mid-semester and end-semester exams so that students' performance is clear. Sometimes students cannot have a good exam on the day of the exam for various reasons, and the exam score should not be used as a criterion for evaluating their performance. Expert 3: periodic evaluation (once every two weeks) of students using updated and correct tests
Space and academic factors	Expert 1: There must be an educational opportunity to implement new teaching methods. Some educational limitations cause the non-implementation of new methods in basic sciences. Expert 2: The educational infrastructure necessary to implement new teaching methods should be available. For example, if the class seminar is to be presented by students, all the prerequisites must be present for a proper and timely presentation. Expert 4: In some classes, due to the large number of students, it is not possible to implement new teaching methods. Most of the students are not benefited from its results.

The second step is to search and identify the organizer themes. Different basic themes were identified and collected in the form of organized themes and all the coded data related to each of the themes. Accordingly, six organizing themes based on the research question were formed, which are presented in Table2.

Table 2. The frequency of themes for the successful application model of new teaching methods in the majors of basic sciences (mathematics and statistics)

themes	interview	Theoretical Foundations	Frequency of interviews	Frequency of theoretical foundations	Total Frequency
Professor (scientific, personality traits)	*	-	11	0	11
Extracurricular and collaborative activities	*	*	11	1	12
Content and headings of statistics	-	*	0	3	3

and mathematics courses					
The skill of interpretation and explanation-argument-combination	*	-	11	-	11
assessment	*	*	11	3	14
Space and academic factors	*	*	8	3	11

In the following, the conceptual model of the research based on the qualitative part is drawn as follows.

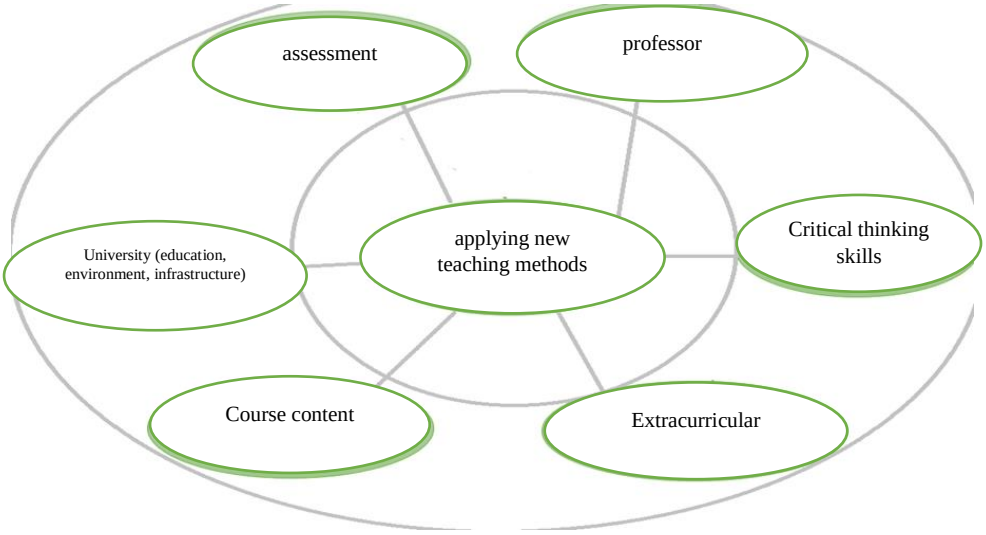

Figure 1. Effective indices on the ideal model of new teaching methods

Table 3 presents the mean and standard deviation of the effective indices in the model of optimal use of modern teaching methods. The average score of critical thinking skills (the level of utilization of critical thinking skills) has the lowest score (2.78) and the average score of the professor (academic, personality traits) (the level of utilization of the professor) has the highest average score (3.10).

Table 3. Descriptive statistics of effective indices in the model of optimal use of new teaching methods

	mean	standard deviation
Professor (scientific, personality traits)	3.1087	0.48
Extracurricular and collaborative activities	3.0674	0.48
Content and headings of statistics and mathematics courses	2.9852	0.56
The skill of interpretation and explanation-argument-combination	3.0886	0.56
assessment	2.7850	0.55
Space and academic factors	3.0193	0.63

In the following, inferential statistics for studying the proposed model are presented in the form of statistical tests at the 5% error level.

A- Normality Test

When the researcher uses structural equations and software, he/she must first comply with the

terms of using the software.To work with Lisrel software, the researcher's data must meet two conditions: First, it should be quantitative and second, it should have a normal distribution.The data of this research has a Likert spectrum and it is quantitative, now it should be checked whether it has a normal distribution or not.In this research, the Kolmogorov-Smirnov test is used to find out about the normality of the distribution of research data.In the Kolmogorov-Smirnov test, when checking the normality of the data, the null hypothesis is The results are presented in the table below.

tested at the 5% error level based on the fact that the data is normal.Therefore, if a greater significance value equal to 5% is obtained, the data distribution will be normal.The normality of the data has been tested at the 5% error level with the Kolmogorov-Smirnov technique.To test the normality of the data, the statistical hypothesisis set as follows.

Null hypothesis: The data distribution is normal.

Alternative hypothesis: The data distribution is not normal.

Table 4. Normality test of the research data

variable	standard deviation	Significance level	Test results
Professor (scientific, personality traits)	0.675	0.321	null hypothesis confirmed
assessment	0.737	0.404	null hypothesis confirmed
Extracurricular activities	0.641	0.096	null hypothesis confirmed
Content of courses	0.737	0.404	null hypothesis confirmed
Critical thinking skills	0.645	0.052	null hypothesis confirmed
University (education-environment-infrastructure)	0.987	0.876	null hypothesis confirmed

According to the results in the above table, the significance level of all variables is higher than 0.05.Therefore, the null hypothesis is confirmed and the research data has a normal distribution.

2. Correlation test between effective indices in the model of optimal use of new teaching methods

Table 5 shows the relationship between indices and the intensity of this relationship.To apply and use the effective components in the optimal implementation of new teaching methods, it was necessary to study the relationship between the mentioned indices.Knowing the relationship between the indices of the mentioned model can be important in analyzing and raising the quality level of teaching methods.The components whose significance level is less than 0.05 (or 0.01) have a significant relationship.Therefore, according to table 5, it can be said that the professor (scientific and personality characteristics) has a significant relationship with the skill of the content of the courses (positive correlation), the university-environment and education-infrastructures (negative correlation).

Table 5. Results of correlation test (Pearson)

		(1)	(2)	(3)	(4)	(5)	(6)
professor (1)	Correlation coefficients	1	-.101	-.114	.362**	.137	.571**
	Significance level		.183	.133	.000	.070	.000

	Number	176	176	176	176	176	176
extracurricular activity (2)	Correlation coefficients		1	.118	.087	-.035	**0.196
	Significance level			.119	.252	.643	.009
	Number		176	176	176	176	176
Evaluation (3)	Correlation coefficients			1	-.053	.247**	-.071
	Significance level				.489	.001	.349
	Number			176	176	176	176
Course content (4)	Correlation coefficients				1	.225**	.434**
	Significance level					.003	.000
	Number				176	176	176
Critical thinking skills (5)	Correlation coefficients					1	.120
	Significance level						.113
	Number					176	176
university (6)	Correlation coefficients						1
	Significance level						00.0
	Number						176

** significance

** Significance at 1% level

3. The degree of use of indices in the optimal model of applying new teaching methods

In this section, using the single-variable Student's t-test, the rate of use of indices in the optimal model of using new teaching methods is investigated.We want to check how effective each of the indices in the model are in implementing and using new teaching methods.Then, using Friedman's ranking test, the priority of the use of critical thinking skills (capacities) in curriculum development is discussed.

Question 5: How much the goals of the first secondary school curriculum are based on critical thinking skills?

Table 6. T-Student test results

	3: Theoretical mean			
Component and skill	mean	t statistic	Degrees of freedom	Significance level
Professor (scientific, personality traits)	3.0707	1.803	85	.073
assessment	2.8011	-2.830	85	.005
extracurricular activities	2.9419	-1.442	85	.151
Course content	3.3284	6.706	85	.000
Critical thinking skills	2.9077	-2.227	85	.027
University (education-environment-infrastructure)	2.8258	-3.410	85	.001

According to the above table, the significance level related to the t-statistic corresponding to the level of utilization of the professor (academic, personality traits) and extracurricular activities in the sample is greater than 0.05 (p-value>0.05).Therefore, it is not possible to comment on the significant positive (negative) effect of this index in the model.In other words, it is not possible to comment on the favorable or unfavorable utilization of these indices in the proposed model.

According to the above table the significance level related to the t-statistic corresponding to the utilization of four evaluation indices, university (education-infrastructure,

environment) and critical thinking skills is less than 0.05 (p-value<0.05).Themean score has a significant negative difference with the theoretical mean.Therefore, it can be concluded that the level of utilization of the mentioned indices in the model of new teaching methods (the proposed model) is at a high and unfavorable level.

Table 7. Friedman's test results regarding the prioritization of effective indices in the proposed model

aspect	mean rank	Importance and impact rating
Professor (scientific, personality traits)	3.77	2
assessment	3.12	5
extracurricular activities	3.39	3
Course content	4.36	1
Critical thinking skills	3.30	4
University (education-environment-infrastructure)	3.06	6
61.73 (0.001)	Chi-square statistic (significance level)	

According to the above table, the level of significance corresponding to the chi square statistic is 0.000, which is less than 5% error.Therefore, the components of critical thinking (six skills) have a significant difference in terms of prioritization and impact on curriculum goals.Also, according to the mean rating, it can be concluded that the course content index with a rating of 4.36 has the most impact (importance) on the optimal implementation of new teaching methods and critical thinking skills (students) with a rating of 3.06 and the least impact and importance on the optimal implementation of new teaching methods.

Validation of The Proposed Model

Researchers deal with two models when working with structural equations: One is a measurement model and the other is a structural model. Research measurement models examine the relationship between latent (hidden) and observed (manifest) variables, and its main application is to examine model fit indices, convergent validity, diagnosis, and composite reliability, which are extracted from the outputs of measurement models. The main output of measurement models is factor loading. Factor loading shows the degree of correlation between latent and observable variables, which is used to calculate convergent validity, diagnostic validity and composite reliability (Ramin Mehr and Charstad, 2014).

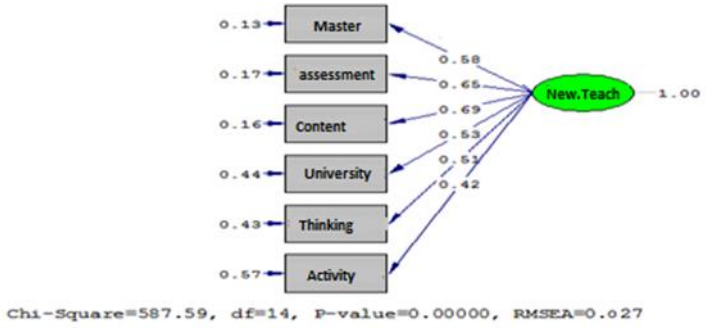

Figure 2. Confirmatory factor analysis of the model (in the case of standard coefficients)

Figure 2 shows that the factor loading of observation in all cases is greater than 0.3, which shows that the correlation between the hidden variable (the structures in the model) and the visible variables is acceptable. After the correlation of the variables was identified, a significance test was performed.

t test was used to check the significance of the relationship between the variables. Since significance is checked at the error level of 0.05, if the t test statistic is greater than the critical value of 1.96, the relationship is significant. According to the findings in Figure 3, the value of the test statistic of some measurement indices of the structures in the model at the 5% error level is greater than 1.96, which means that the observed correlations are significant.

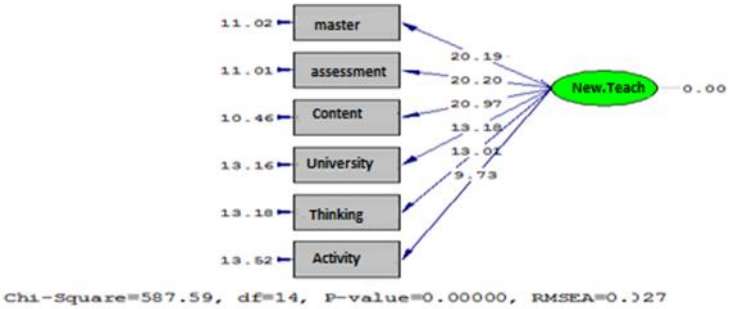

Figure 3. confirmatory factor analysis of the model (in the case of significant coefficients)

Table 8. Confirmatory factor analysis

index	Fitting values
Chi-square/Df	41.92
NFI	0.91
CFI	0.90
GFI	0.92
IFI	0.84

Conclusion

In this research, six effective indices on the optimal implementation of new teaching methods in basic sciences (statistics and mathematics) were identified. It was shown that the index of course content has more impact and importance in the proposed research model and also the index of critical thinking skills has been under estimated. This means that these skills have not been paid attention to at lower levels of education, which now show their weakness more strongly at higher levels. Unfortunately, the teaching method in statistics and mathematics fields in universities is still traditional and lecture-based, and as a result, the professor's evaluation methods for students are traditional.This issue has caused students to choose lower level universities for further education in higher levels (supplementary education).In this way, scientific capacities and potentials for flourishing are wasted.Quantitative research results showed that students' critical thinking and evaluation skills in the proposed model are at a low level.Therefore, it is necessary to provide the existing mechanisms to improve these two indices in the fields of basic sciences

and create a platform for the application of these fields.For this purpose, the change evaluation method should be changed according to the teaching method. Also, critical thinking skills such as interpretation,

explanation, problem solving and innovation skills were used in the presentation of class materials and the class evaluation has not been only focused on mid-semester and end-semester grading.

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