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Developing a Standard Learning Model with a Conceptual Map and Using the Network Process Analysis Method for Students

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Abstract

Introduction: Today, the use of new methods in the development of advanced educational methods has a special place, therefore, the present research was conducted with the aim of developing a standard learning model with a conceptual map and using the network process analysis method for students.

Research method: The current research is based on a practical research goal and was conducted using the Delphi research method and the network process analysis method of multi-criteria decision-making methods. The statistical population includes experts, professors and professors specializing in chemistry education in the academic year 2020, of which 30 people were selected by targeted sampling. The tools used include in-depth and semi-structured interviews and researcher-made paired comparison questionnaires. Data were analyzed using Super Decisions software.

Findings: The mathematical layer with a weighted average of 0.652, the physical layer 0.235, and the chemical layer 0.113 had the greatest effect, respectively. In each layer of physics, mathematics and chemistry, the results were significant and approved.

Conclusion: According to the effect of prerequisites and concepts and their prioritization, a conceptual map of the subject of chemical atom structure can be prepared and also by using the network process analysis method, educational concepts can be ranked and used. In teaching and learning standards and reducing the amount of educational errors

Keywords: Conceptual map, Education, network process analysis method, Standard learning, the subject of chemical atom structure

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Introduction:

Learning is one of the necessities of every individual's life and is a process in which knowledge is created through the transformation and evolution of experience (1). Some consider learning as the acquisition of knowledge and information, various habits, diverse skills, and different ways of solving problems, and the most famous definition considers learning as the process of creating relatively permanent changes in behavior or behavioral ability resulting from experience (2). To increase learning, the acquisition of relevant knowledge, information, and skills, various teaching and learning methods are used that influence and promote the knowledge of individuals. Education includes any pre-planned activity or measure aimed at facilitating learning in learners, in addition to the teacher's classroom activities, education includes the design of education and the implementation of evaluation as well (3).Corresponding to the expansion of various skills in life, the learning and education of every society needs quantitative and qualitative improvement. In the current conditions, the rapid expansion of technology has changed the way of learning (1). Researchers believe that the cognitive revolution has considered learning as an active process in which learners try to understand what they are studying. Realizing the cognitive approach to learning has made the change in the paradigm of teaching and learning necessary. In this regard, the role of teachers should change from the traditional role of transmitter or provider of knowledge to the role of facilitator, to increase the motivation of students for learning and thus incorporate new meanings into their previous knowledge. In this regard, awareness of the importance of students' previous knowledge in guiding them to meaningful understanding has a special importance and position. This issue prompted Novak and Gowin (1984) to produce an educational substitute: conceptual maps.Follow-up studies have shown that the emergence of conceptual maps is a special tool in dealing with problems related to the processes of teaching and learning and is the inspiration for much research in this field (4).

The findings of a study on conceptual maps showed that conceptual maps are widely used in promoting meaningful teaching and learning. These conceptual maps are not only useful in displaying the qualitative aspects of student learning, but are also used as learning and assessment tools, reinforcing learning, and even facilitating curriculum planning. They are also widely used as "roadmaps" and as an exploratory device (5). Based on the research conducted, a conceptual map is useful for knowledge transfer in five stages of learning: acquisition, connection, application, acceptance, and absorption. The perceptual strategy or conceptual mapping (concept mapping) teaching improves knowledge transfer performance because it facilitates the application of knowledge for the learner (students). They use the conceptual map perceptual strategy to gain insight into new and existing knowledge. Moreover, concept mapping can help students develop good learning habits, which may help with future knowledge transfer. Research has also shown that concept mapping increases students' academic achievement (6).

On the other hand, the rapid expansion of technology has led to the emergence of a new type of learning called e-learning. For this reason, improving the educational system and learning, teaching methods and educational planning have been of interest today. Researchers have often defined e-learning as the use of remote communication technology to deliver and learn

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educational and training information (7). For example, in situations like the COVID-19 pandemic, the need for e-learning, distance education and virtual education was a necessity. In this context, the need for effective educational models was felt more than ever (8). However, the development of e-learning in teaching and learning requires appropriate educational theories and models (9). One of the innovative teaching-learning strategies in this area is the use of conceptual maps. The use of conceptual maps enables teachers and students to deepen the teaching-learning process and creates the conditions for achieving higher cognitive levels and types of abstract, creative and critical thinking (10).

One of the important advantages of conceptual maps is their ability to correct misconceptions in learners. The use of conceptual maps creates a meaningful relationship between concepts, which leads to the organization and identification of relationships and prevents the formation of misconceptions. Conceptual maps help students analyze a problem from different perspectives, develop a different way of thinking, and expand their knowledge network and attitudes for effective use of concepts. At the same time, it transforms learning into an active process, supports visual presentation and focus on concepts, facilitates learning, improves student understanding and retention of information, and also helps students in studying and reviewing [11].

Conceptual maps come in various forms and can generally be categorized into two main types: standard conceptual maps and non-standard conceptual maps. Non-standard conceptual maps can be created by different individuals (instructors and learners). These conceptual maps are related to the literacy level of the person creating them [4] and usually contain learning errors. This is because individual differences, the level of knowledge of individuals, lead to the creation of different types of conceptual maps even in a specific topic, and therefore these significant differences lead to the creation of learning errors that need to be corrected. Standard conceptual maps, on the other hand, are prepared by researchers in an academic manner with the help of interviews with experts and specialists in that particular field, and using appropriate research techniques, methods and calculations [12, 13, 14]. In this method, the amount of error and misunderstanding is significantly reduced and is more reliable. The impact of these standard conceptual maps on learning in that domain is also specified. These standard conceptual maps can be used to produce teacher's content and pedagogical knowledge, produce electronic content, and the like, so that they can teach error-free [15].

Standard conceptual maps can also be examined and prepared from two perspectives: 1) conceptual maps of correct learning (14) and conceptual maps of misconceptions (13), 2) another issue is the preparation of various types of conceptual maps from different perspectives: the educational model, which is a pattern of the learning process of a concept, designed using the learner model and for the purpose of decision-making about the necessary tools and strategies for teaching that concept. Mental patterns and processes and ways of perceiving and receiving concepts are among the things that can be obtained in three ways: a) conceptual map from the learner's (student's) perspective (13), b) conceptual map from the instructor's (teacher's) perspective (4), and c) conceptual map from the experts' perspective (16).

Experts, scholars, and textbook authors who are mostly active in academic centers can design appropriate conceptual maps, especially when the discussion of conceptual maps involves considering and designing different layers (prerequisites) of course topics. The higher levels of education of specialists in each field of knowledge can draw more accurate conceptual maps by considering details. The limitation of this method, given the large population of learners and educational topics, is the accessibility and utilization of these experts and scholars in the development of conceptual maps and the production of educational content knowledge and pedagogy .Discovering the empirical model of the correct conceptual map and misconceptions, which also includes layers, can assist authors in the areas of teaching, assessment, and curriculum planning. In the field of teaching, one can identify different teaching components, the relationships between these components, and their prioritization. In the assessment section, it can provide a detailed and comprehensive assessment of the individual's performance in the relevant field. Finally, it can assist curriculum planners, authors, and teachers in making changes to the educational content and the way of expressing and teaching textbooks in order to ensure that learners receive the concepts correctly and directly and improve the quality of learning [15]. As another example, the discussion of knowledge layers (prerequisites) in each topic is raised. For instance, in some chemistry topics, the layers (prerequisites) of physics and mathematics are also discussed. Chemistry topics are such that sometimes they need to be learned theoretically and sometimes practically. At the same time, the student needs to know mathematics and physics to some extent, which varies in each part of the chemistry course.

Experts, scholars, and textbook designers who are mostly active in university centers can design appropriate concept maps, especially when the discussion of concept maps involves considering and designing different layers (prerequisites) of course topics. The higher levels of education of experts in each field of knowledge can draw more accurate concept maps by considering details. The limitation of this method, considering the large population of learners and educational topics, is the access and use of these experts and scholars in developing concept maps and producing educational content and pedagogy. Discovering the correct conceptual map model and misconceptions that also include layers can help authors in three dimensions of teaching, assessment, and curriculum planning. In the field of teaching, one can identify different parts of teaching, the relationships between these parts, and their priorities. In the assessment section, it can also provide an accurate and complete assessment of the individual's performance in the relevant field. Finally, it can help curriculum planners, authors, and teachers to make changes in the educational content and the way of expressing and teaching the textbooks in order to receive the presented concepts correctly and directly by the learners and improve the quality of learning as another example, the discussion of knowledge layers (prerequisites) in each topic is raised. For instance, in some chemistry lessons, the layers (prerequisites) of physics and mathematics are also discussed. The topics in the chemistry course are such that sometimes they need to be learned theoretically and sometimes practically. At the same time, the student needs to know mathematics and physics to some extent, which is different in each part of the chemistry course.

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Nevertheless, the common method of teaching science concepts in our schools today is the teacher-centered lecture method, and students only have a completely passive role, while teachers play an active role and have full control over the entire teaching and learning process. Despite the wide range of criticisms due to the limited effectiveness of this method in teaching and learning science, and studies have shown that regardless of the teachers' efforts to address students' misconceptions through the conventional lecture method, most students come out of science classes with various incorrect perceptions about different science concepts .This shows that this teaching method has failed to provide a solution to the problems and misconceptions of the students. Consequently, the need for alternative teaching strategies to minimize or possibly eliminate misconceptions should not be overlooked. Although researchers have examined various scientific concepts and teaching methods in the process of providing a solution to this problem, there are limited studies on the use of conceptual map instruction, and in this regard, the conceptual map considering its prerequisites has not been fully examined, and no accessible study was found On the other hand, the use of mathematical techniques in the development of advanced teaching methods has a special place today, so the present study was conducted with the aim of developing a standard learning model with a conceptual map and using the network process analysis method for students

Research method:

This research is based on an applied goal, and the Delphi research method was used to conduct it. The Analytic Network Process (ANP) method, which is a Multi-criteria decision-making, was utilized to analyze the data. The statistical population of the study consisted of experts and professors in chemistry education during the years 2020-2021. In this research, the purposive sampling method, which is one of the non-probability sampling?

Methods, was used to select the sample. The concept of purposive sampling, which is commonly used in qualitative research, means that the researcher selects study participants and locations based on their potential impact on understanding the research problem and the central phenomenon [18].

From the above statistical population, 30 individuals including experts and professors of chemistry education were selected. In this sample group, there were 16 university professors from teacher training universities, two professors from Shahid Rajaee Teacher Training University, and twelve high school chemistry teachers (with master's and doctoral degrees). It should be noted that all the experts are active in the field of chemistry education.

Data collection tool in the first stage of the in-depth and semi-structured interviews was used. The interviews were conducted in three sessions, and each was implemented separately. The qualitative data obtained from the interviews were analyzed using the coding method in three stages of open coding, axial coding, and selective coding. To increase the reliability of the data, the findings were reviewed and confirmed by the sample group experts at each stage of coding. Finally, the concepts related to the topic of atomic structure in chemistry were extracted based on its prerequisites, and the results showed that there are three layers (chemistry, physics, and mathematics) and 34 concepts that learners need to know in order to learn the topic of atomic structure in chemistry. The chemistry layer contains 6 concepts, the physics layer contains 16 concepts, and the mathematics layer contains 12 concepts.

Table1. Output Table of Coding Information

Layers related to the topic of atomic structure in chemistry.	**Concepts Related to Each Layer**
Chemistry	Electron configuration, Energy levels, Subatomic particles, Emission spectrum, Quantum model, Application of electron configuration
Physics	Classical and quantum physics, Radioactive rays, Centripetal force, Quantum numbers, Electric discharge, Electric charge, Electric field and units, Calculation of force and electric field, Charged particles, Matter, Energy quantization, Electric charge, Proton and electron, Energy and its types, Conversion of different types, Magnetic field on moving electric charge, Light refraction to different wavelengths, Mass and its unit, Electron motion in fixed orbits (Bohr), Nature and properties of light as a form of energy and electromagnetic type
Mathematics	Prime numbers and its four fundamental operations, Sinusoidal waves and wave concept, Trigonometric functions, Power and exponential numbers, Angle, Mean and weighted mean,

The results of this stage were distributed among these experts through a questionnaire on the concepts. The questionnaire consists of 204 questions designed according to the paired comparison scale, and the experts and stakeholders determined the importance of each index relative to other indices. Then, the information was analyzed using Super Decisions software.

Results:

The results of the study showed that for the reliability of the questionnaire, Cronbach's alpha was used, which resulted in 0.84 for the overall responses, indicating that the questionnaire has reliability In this questionnaire, pairwise comparison numbers using the 1-9 Saaty scale were used (Table 2). These matrices were provided to experts and specialists to perform pairwise comparisons with respect to these criteria

Table 2. Verbal expressions for pairwise comparisons to express the degree of importance

numerical value	**Degree of significance in two-by-two comparisons**
1	Equal preference
2	Equally to relatively preferred
3	Relatively preferred
4	Relatively too strongly preferred
5	Strongly preferred

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6	Strongly to very strongly preferred
7	Very strongly preferred
8	Very to infinitely preferred
9	Infinitely preferred

First, a conceptual model of the prerequisites for the topic of chemical atomic structure was drawn in the Super Design software. It is worth noting that the criteria and sub-criteria were obtained from in-depth and semi-structured interviews after creating the model in the software, the criteria were ranked using the Analytic Network Process (ANP) method, which we will discuss further

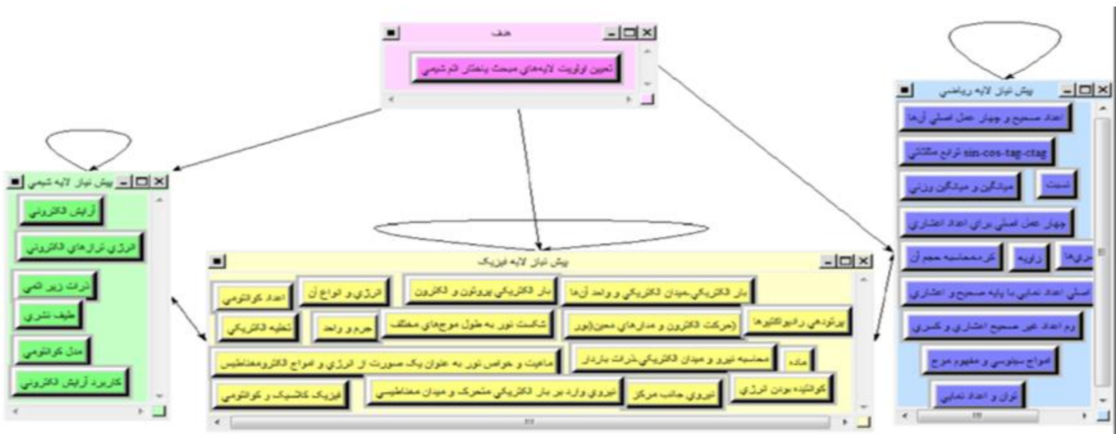

Figure 1 depicts the conceptual model for determining the priority of the layers (prerequisites) of the topic of chemical atomic structure, which was drawn in the Super Design software

A) Ranking criteria using the Analytic Network Process (ANP) method

In this section, the criteria were weighted using the ANP method. To do this, a 3*3 matrix was formed, where the rows and columns consisted of the identified factors in this study. All matrices were transformed into an equivalent matrix by taking the geometric mean of all numbers, and the data were entered into the SuperDecisions software questionnaire section. The weights obtained were ranked using the eigenvector method.

Table 3. Calculated weights and ranks using the Analytic Network Process (ANP) method

Criteria for ranking	**weight of each criterion**	**rank**
Prerequisite of chemistry layer	0.113	3
Prerequisite of mathematics layer	0.652	1
Prerequisite of physics layer	0.235	2

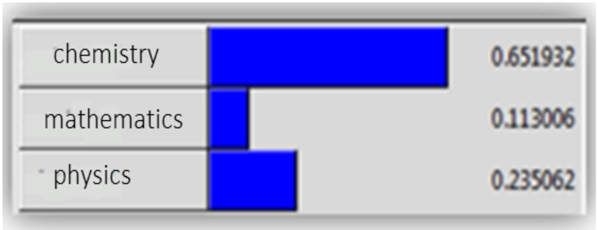

Figure 4. Graphic representation of the final ranking of prerequisites for the topic of atomic structure in chemistry.

As shown in the table above, the mathematics layer has the greatest impact. It should be noted that to ensure the validity of the results, the compatibility comparison matrix of this matrix was also examined.

Table 4. Consistency calculation indices

Index	Value
Incompatibility index	0.035
Random index	0.58
incompatibility rate	0.060

Since the obtained value of the consistency ratio is less than 0.1, it can be stated that the comparison matrix is reasonably consistent.

B) Ranking of sub-concepts of the chemistry layer using the Analytic Network Process (ANP) method

In this section, the sub-concepts of the chemistry layer were weighted using the ANP method. To do this, a 6*6 matrix was formed, where the rows and columns consisted of the identified factors in this study. All matrices were transformed into an equivalent matrix by taking the geometric mean of all numbers, and the data were entered into the Super Decisions software questionnaire section. The weights obtained were ranked using the eigenvector method.

Table 5. Calculated weights and ranks using the Analytic Network Process (ANP) method

Ranking indicators	weight of each criterion	rank
Emission spectrum	0.138	4
Electron configuration	0.116	5
Subatomic particles	0.407	1
Energy levels of electrons	0.168	2
Quantum model	0.157	3
Application of electronic configuration	0.010	6

As shown in the table above, the sub-concept of subatomic particles in the chemistry layer has the greatest impact. It should be noted that to ensure the validity of the results, the compatibility comparison matrix of this matrix was also examined.

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Table 6. Consistency calculation indices

Index	Value
Incompatibility index	0.082
Random index	1.24
incompatibility rate	0.066

Since the obtained value of the consistency ratio is less than 0.1, it can be stated that the comparison matrix is reasonably consistent.

C) Ranking of sub-concepts of the mathematics layer using the Analytic Network Process (ANP) method.

In this section, the sub-concepts of the mathematics layer were weighted using the ANP method. To do this, a 12*12 matrix was formed, where the rows and columns consisted of the identified factors in this study. All matrices were transformed into an equivalent matrix by taking the geometric mean of all numbers, and the data were entered into the SuperDecisions software questionnaire section. The weights obtained were ranked using the eigenvector method.

Table 7. Calculated weights and ranks using the Analytic Network Process (ANP) method

Criteria for ranking	weight of each criterion	rank
Integer number Four Basic Operations in Moths	0.291	1
Sinusoidal waves and the concept of wave	0.014	11
Trigonometric functions	0.015	5
Powers and exponential numbers	0.104	9
Angle	0.038	10
Mean and weighted mean	0.019	7
Relativity	0.064	6
The concept of integers, decimals, and fractions	0.094	3
Four basic operations for decimal numbers	0.134	4
Four basic operations for exponential numbers	0.130	2
Series	0.168	8
Sphere and its volume	0.054	12

As shown in the table above, the sub-concept of Integer number Four Basic Operations in Moths in the mathematics layer has the greatest impact. It should be noted that to ensure the validity of the results, the compatibility comparison matrix of this matrix was also examined.

Table 8. Consistency calculation indices

Index	Value
Incompatibility index	0.073
Random index	1.48
incompatibility rate	0.049

Since the obtained value of the consistency ratio is less than 0.1, it can be stated that the comparison matrix is reasonably consistent.

D) Ranking of sub-concepts of the physics layer using the Analytic Network Process (ANP) method.

In this section, the sub-concepts of the physics layer were weighted using the ANP method. To do this, a 16*16 matrix was formed, where the rows and columns consisted of the identified factors in this study. All matrices were transformed into an equivalent matrix by taking the geometric mean of all numbers, and the data were entered into the SuperDecisions software questionnaire section. The weights obtained were ranked using the eigenvector method.

Table 9. Calculated weights and ranks using the Analytic Network Process (ANP) method

Ranking indicators	Weight	Rank
Classical and Quantum Physics	0.097	10
Radioactive radiation	0.103	9
Centripetal force	0.169	3
Quantum numbers	0.052	12
Electric discharge	0.158	4
Electric charge, electric field, and their units	0.138	5
Calculation of electric force and electric field - Charged particles	0.132	7
Matter	0.381	1
Quantization of energy	0.066	11
Electric charge, proton, and electron	0.134	6
Energy and its types, and conversion of different types	0.037	13
Force on a moving electric charge in a magnetic field	0.117	8
Refraction of light at different wavelengths	0.014	15
Mass and its unit	0.282	2
Electron motion in specific orbits (Bohr	0.011	16

model)		
Nature and properties of light as a form of energy and types of Electromagnetic waves.	0.028	14

As shown in the table above, the sub-concept of matter in the physics layer has the greatest impact. It should be noted that to ensure the validity of the results, the compatibility comparison matrix of this matrix was also examined.

Table 10. Consistency calculation indices

Index	Value
Incompatibility index	0.062
Random index	1.59
incompatibility rate	0.039

Since the obtained value of the consistency ratio is less than 0.1, it can be stated that the comparison matrix is reasonably consistent. The results obtained from the prerequisites (Chemistry, Physics, and Mathematics) for the sub-concept of atomic structure in Chemistry are shown in the following diagram.

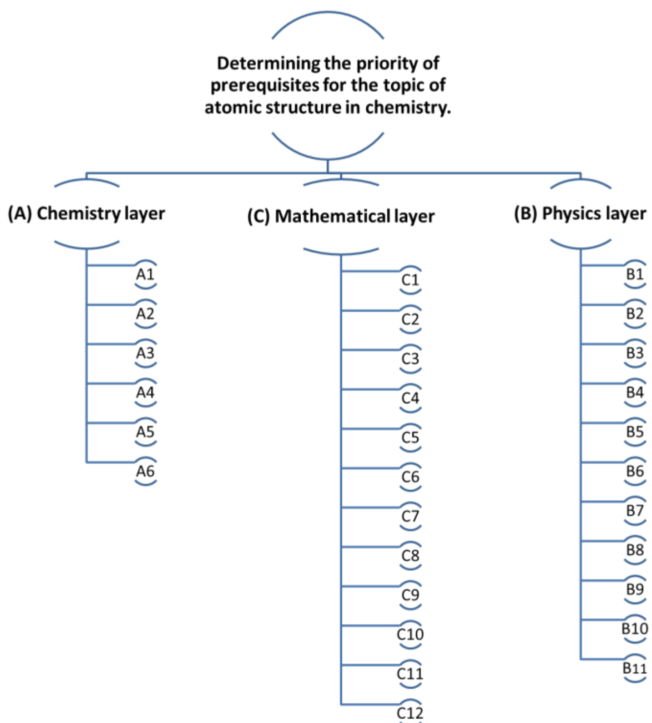
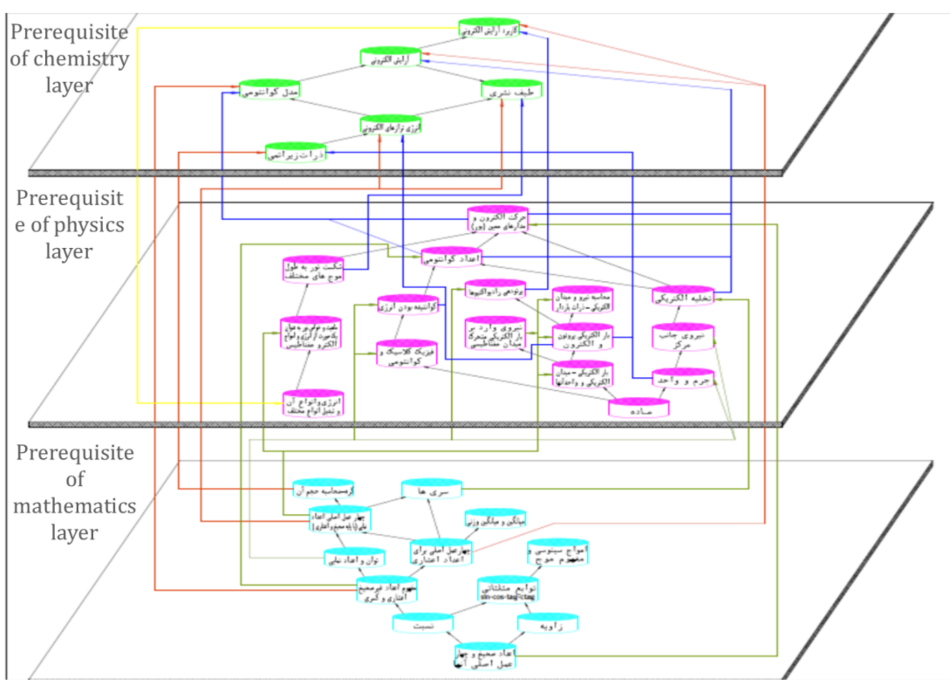


Diagram 3. Final output of the ANP-based model for the atomic structure sub-concept in Chemistry, ranked by the ANP method using the Chemistry, Mathematics, and Physics layers

A1 Subatomic particles A2 Electron energy levels	B7 Four basic operations for exponential numbers	C8 Force on a moving electric charge in a

A3 Quantum model A4 Emission spectrum A5 Electronic configuration A6 Application of electronic configuration B1 Integers and their four basic operations B2 Ratio B3 Angle B4 Trigonometric functions: sin-cos-tan-cot B5 Concept of non-integer, decimal, and fractional numbers B6 Powers and exponential numbers (	B8 Four basic operations for decimal numbers B9 Sinusoidal waves and the concept of wave B10 Mean and weighted mean B11 Series B12 Sphere and its volume calculation C1 Matter C2 Mass and its unit C3 Centripetal force C4 Electric discharge C5 Electric charge, electric field, and their units C6 Electric charge, proton, and electron C7 Calculation of electric force and electric field - Charged particles	magnetic field C9 Radioactive radiation C10 Classical and Quantum Physics C11 Quantization of energy C12 Quantum numbers C13 Energy and its types, and conversion of different types C14 Nature and properties of light as a form of energy and types of Electromagnetic waves. C15 Refraction of light at different wavelengths C16 Electron motion in specific orbits (Bohr model



"Diagram 4. The final model of the standard learning pattern with a conceptual map and using the network process analysis method on the topic of the atomic structure of chemistry, considering the mathematical, physical, and chemical prerequisites for students."

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Discussion and Conclusion:

The present research was conducted with the aim of developing a standard learning model with a conceptual map and using the network process analysis method for students in the subject of atomic structure in chemistry. The standard learning model with a conceptual map and the use of network process analysis method in the above-mentioned topic was obtained and formulated. The results showed that, in sequence, the layers of mathematics, physics, and ultimately chemistry are effective in learning the subject of atomic structure in chemistry.

Furthermore, the findings showed that in the prerequisites of the Chemistry layer, the concepts of subatomic particles, quantum model, electron energy levels, electronic configuration, emission spectrum, and application of electronic configuration have the greatest impact, respectively. In this regard, no study was found that specifically addressed the necessary prerequisites for teaching and learning this sub-concept, so comparison of studies is not possible. However, in a study conducted by Alizadeh Kohi Khili [14] on the correct learning pattern and determination of the learner's empirical model using a conceptual map in the atomic structure sub-concept in Chemistry, the ranking results of the Chemistry layer concepts in this study were consistent with those of Alizadeh's study, confirming them. In this regard, it can be said that the results of the correct learning pattern of the atomic structure sub-concept in Chemistry from the learner's perspective (students) are consistent with the experts' perspective. Alizadeh obtained the correct learning pattern of the atomic structure sub-concept in Chemistry from the learner's perspective (students) using the Structural Equation Modeling (SEM) method, which is shown in the following diagram.

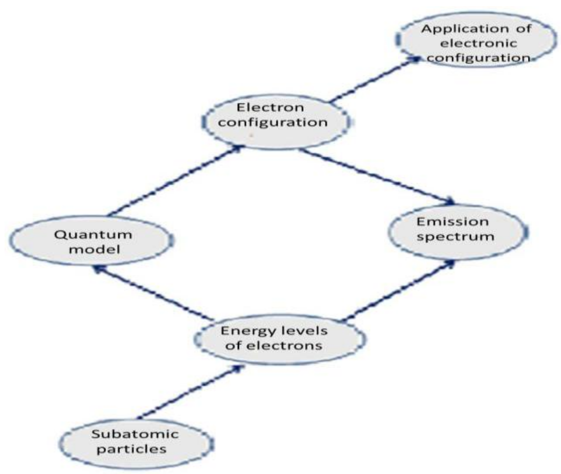

Diagram 5. Theoretical model of the standard conceptual map of the correct learning pattern in the atomic structure sub-concept in Chemistry (Alizadeh Kohi Khili, 2012[14]).

In the present study, this model was also confirmed by experts, and the results obtained from ANP calculations showed that in the prerequisites of the Chemistry layer, the concepts of subatomic particles, electron energy levels, quantum model, emission spectrum, electronic configuration, and application of electronic configuration have the greatest impact, respectively.

This finding is consistent with Alizadeh's study, despite differences in the statistical population and calculation methods and from two different perspectives (learners and experts).

On the other hand, the results showed that in the prerequisites of the Physics layer, the concepts of matter, mass and its unit, centripetal force, electric discharge, electric charge, electric field and its unit, proton and electron, calculating force and electric field - charged particles, force on a moving electric charge in a magnetic field, radioactive rays, classical and quantum physics, quantization of energy, quantum numbers, energy and its types, conversion of different types, nature and properties of light as a form of energy, and various types of electromagnetic radiation, light refraction into different wavelengths, and electron motion in specific orbits (Bohr) have the greatest impact, respectively. At the same time, the findings showed that in the prerequisites of the Mathematics layer, the concepts of integers and their four basic operations, ratio, angle, trigonometric functions (sin-cos-tan-cot), concept of non-integer, decimal, and fraction numbers, power and exponential numbers, four basic operations for exponential numbers, four basic operations for decimal numbers, sinusoidal waves and wave concept, mean and weighted mean, series, sphere and its volume calculation have the greatest impact, respectively. In this regard, no study was found that specifically addressed the necessary prerequisites for teaching and learning this sub-concept, so comparison of studies is not possible. Studies have been conducted on standard concept maps, including, for example, studies on the correct and incorrect learning patterns in chemistry and particularly the chemistry atomic structure. Alizadeh Kouhi has designed a standard concept map for the correct learning pattern of the chemistry atomic structure [14]. On the other hand, Mani [13] obtained the incorrect learning pattern in the context of education and learning. During education and learning, there are correct and incorrect learning patterns, so both correct and incorrect learning maps should be prepared in the educational process. For example, studies have shown that during the study of chemistry, teachers and students may encounter misconceptions when dealing with abstract scientific concepts related to the atomic structure, such as quantum theory and quantum numbers, when examining the properties and behaviors of chemical substances at the atomic and molecular levels. However, since if misconceptions are not identified and corrected, they will remain for a long time and act as a barrier against cognitive processes, they should be recognized and eliminated as soon as possible. Based on this, concept maps can be used to develop correct learning patterns and explain how misconceptions are related to each other and how they affect each other [20, 13]. Regarding the results, it can be said that in developing a concept map, prerequisite layers should be considered, and the concept map should be developed using prerequisites and considering the concepts of each prerequisite layer and the importance and impact of that concept in each subject of the course.

In the explanation of the findings, it can be said that today, improving the educational system and learning and educational methods have been taken into consideration and the relationship between high academic performance which originates from the educational system (19) directly or indirectly with mental health variables has been investigated and confirmed (20). Concept maps are one of the teaching and learning strategies that lead to a deeper learning process. The common method of teaching science concepts in our schools is teacher-centered lecturing, despite the wide range of criticisms due to its limited effectiveness in teaching and learning science. Furthermore, students have a completely passive role, while teachers play an active role and have mastery over the entire teaching and learning process. It is obvious that recent trends have shown that despite the efforts of teachers to address students' misconceptions with the existing traditional lecturing method, students often leave science classes with various misconceptions about different concepts. This indicates that this teaching method has failed to provide a solution to the problem of students' misconceptions. Therefore, the need for alternative teaching strategies that are useful in minimizing or possibly eliminating misconceptions should not be overlooked. In this regard, a concept map is an effective strategy for correcting students' misconceptions.

Research limitations and Recommendations: Although researchers have examined various scientific concepts and teaching methods in the process of providing a solution to this problem, the use of concept mapping instruction in addressing students' misconceptions has not been fully investigated, and there are limited studies in this area. Additionally, developing a standard concept map from the perspective of experts that is prepared using accurate research and calculation methods has a significant role in reducing learning errors. On the other hand, the concept of PCK refers to the intersection of pedagogical and content knowledge domains. In this context, "pedagogical content knowledge" (PCK) refers to the combination of subject matter knowledge and knowledge about teaching and learning. The shared domain of knowledge or pedagogical content knowledge (PCK) is recognized as a way to represent and organize subject matter knowledge in a way that makes it tangible and comprehensible for learners. PCK can be used to generate effective instructional patterns (free from errors, based on PCK and conceptual maps) for teaching to learners such as students and other individuals. This PCK can be produced based on a conceptual map and utilized for teaching through an error-free instructional pattern founded on PCK and the conceptual map. It is also suggested that future studies use a more extensive statistical community, for example, in the present study, a sample of professors and experts working in the field of chemistry and chemistry education was selected, and it is necessary to consider a statistical community of professors and experts in those courses based on the study's prerequisites. In future research, in addition to chemistry specialists and experts, physics and math specialists and experts should also be utilized. Additionally, in future studies, it is recommended to employ uncertain methods such as fuzzy ANP. Along with each study, there are limitations; in this study, due to the high number of questionnaire questions, a lot of time was spent collecting data. Furthermore, in this research, a new conceptual model and mathematical method were presented for developing a conceptual map. Over the past three decades, hierarchical models and the hierarchical decision-making process have been used in various decision-making areas, but this type of research is lacking in the teaching and learning methods field, which poses limitations in the background and comparison of studies.

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