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Assessment of Students' Qualification using Integrated Analytical Hierarchy Process

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Abstract **- At present, it is very important for universities to improve the comprehensive qualifications of students and social competitiveness. As society develops and the recruitment of students continues to expand, the challenges and difficulties faced by students graduating are also growing. It is a core requirement of the development of university education to evaluate students' qualifications objectively and accurately and to give appropriate education accordingly.**

Establishing an objective and comprehensive student qualification assessment system to bring education closer to more realistic needs and provide more comprehensive and accurate data when organizations choose students is an important task in university work.

Although several universities have already had considerable success in terms of qualification management, teaching management, and so on, further improvements in the assessment system of students' qualification are a real challenge for change and development. On the other hand, when assessing students' qualifications in many universities, such an approach often lacks scientific and objective qualities to assess students' overall performance using a series of qualitative methods.

In paper, we have implemented an assessment system of students' qualification that combines qualitative and quantitative factors using an integrated hierarchical process (IAHP) tool developed in the Net-oriented System Description Language (NSDL) environment, which combines the advantages of Petri nets and object-oriented programming languages to provide scientific, objective, intuitive and flexible evaluation systems.

Keywords - IAHP, Qualification Assessment, Petri Net, Object-oriented Programming Language, Net-oriented System Description Language,

1. INTRODUCTION

Analytical Hierarchy Process (AHP) is a comparative assessment method using human perception, which is a decision-making method that selects the best of the various alternatives selected by modeling the actions of the decision-making factors in a hierarchical structure.

AHP is widely used in various fields of economy, military, society, management, education, medicine, etc due to its ability to deal with qualitative (fuzzy) or quantitative data, logical, systematic, simple and effective analysis.

Developing a convenient and reliable decision-making tool has great practical significance.

In the past, AHP tools have been developed and used mainly in a graphical user interface, with a strong spreadsheet and a table-based Execl program, such as XLSTAT, AHP Decision, AHP Solver, AHPcalc, AHP-jar, FuzzyAHP, and Ahp_Calculator[1-8].

These tools have already been used for hierarchical analysis by using the appropriate input to users based on a hierarchical model built with image or graphical modeling tools. In other words, there was a lack of automatic informational links between the hierarchical model building and the hierarchical analysis module. Finally, when the number of layers, criteria, and alternatives are large and the interaction is complex, the overall analysis is time consuming and laborious and the complexity of users' use is unavoidable.

The characteristics of the proposed IAHP and other AHP tools are shown in Table 1.

In addition, there are many software development tools that combine the advantages of Petri nets and object-oriented programming languages with good intuition and convenience in modeling in the world [9-16].

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***Table 1**. AHP tool comparison*

AHP tools	Modeling Language	AHP Structure Diagram Model	Qualitative Criteria	Quantitative Criteria
XLSTAT	Excel	-	✓	-
AHP Decision	Java	-	✓	-
AHPcalc	Excel	-	✓	-
AHP-jar	Java	-	✓	-
FuzzyAHP	R	-	✓	-
Ahp_Calculator	Python	-	✓	-
IAHP	NSDL	✓	✓	✓

✓ This means “supported”, - “no support”

Hence, we developed IAHP in NSDL environment that was developed by combining the advantages of Petri nets and object-oriented programming languages. In IAHP, the hierarchical structure model is described by Petri net diagrams to enhance the intuition and convenience of the AHP tool.

2. INTEGRATED ANALYTICAL HIERARCHY PROCESS TOOL

2.1 Net-oriented System Description Language- NSDL

The NSDL (Net-oriented System Description Language) is an independent software development tool that uses the Petri nets and object-oriented programming language VB based on Microsoft.NET Framework 4.0 libraries.

The formal representation of NSDL is as follows.

$$NSDL = [P, T, A, M, F, \theta, O] \quad (1)$$

Where,

- P is the finite set of places,
- T is the finite set of transitions,
- A is the finite set of arcs,
- M is the finite set of markings (includes the object tokens),
- F is the finite set of functional code,
- θ is the finite set of attributes (delay time after firing, firing rate, priority, weight, capacity, type of elements, competition extraction setting and color, etc.) and
- O is the finite set of user-defined objects modeled with NSDL’s functional codes.

In NSDL, systems are modeled as follows.

- In the upper level of system,
  - Diagram models are constructed according to the mutuality and the logical action sequence of system components.
  - Graphical User Interface models can be configured according to the demands of the user. (optional)
  - Setting properties of diagram and interface elements
- In the lower level of system,
  - Standard and user defined functional code model of upper level diagram elements are edited.
  - Dynamic setting properties of diagram and interface elements by functional codes during the simulation.

In NSDL, we introduced elements such as in/out place terminal, equal place and subsystem, functions such as model library management, code debugging and model compiling to further improve its flexibility, convenience, extensibility and productivity.

2.2 Integrated Analytical Hierarchy Process (IAHP) Method

2.2.1. Algorithm diagram of IAHP

The algorithm diagram of IAHP is shown in Fig. 1.

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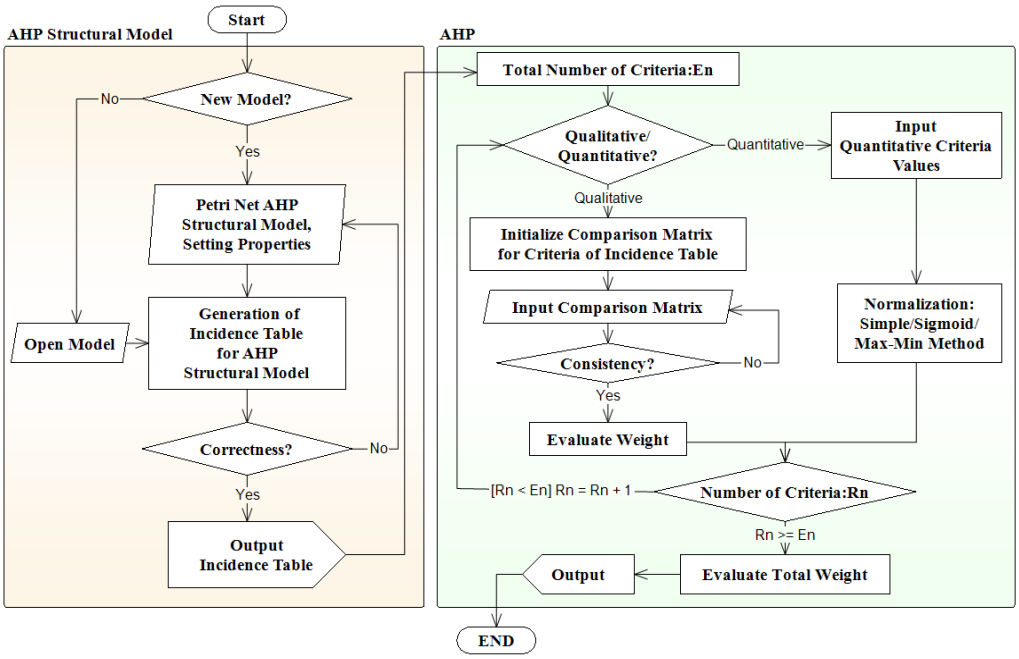

Figure 1. *Algorithm diagram of IAHP.*

The process of making AHP structure model in tool is as follows.

① Hierarchical Structure Modeling Module

- User can used one goal layer element (A1), 17 criteria layer elements (B1- K1), one alternative layer element (S1) and one reference arc element to model hierarchical structure, also one sub-criteria and sub- alternative element by subsystem element. These elements are created and stored in the Hierarchical Analytical Library file “ahp.ndt”.

- Insert the model library file “ahp.ndt” into the toolbox.

- Using the modeling elements in the toolbox, create an AHP structural model that the user needs and add the attributes for the example (Fig. 8-9).

- For convenience, If there are so many criteria (or alternatives) in one layer can be used as sub-criteria (alternatives).

② Generation of incidence table, checking and revising for hierarchical structure model

- Generates incidence table according to the relationship of each element in the hierarchical structure model (Table 1).

- The user checks the consistency of the built-in hierarchical structure model with the generated incidence table and performs modifications and storage of the built-in model.

③ AHP module

- Based on the incidence table obtained from the created AHP structural model, we implement AHP algorithm using the VB script language of NSDL.

- The user can directly input qualitative and quantitative criteria. Also, the NSDL’s script language and the best GIS analysis tool ArcGIS were combined to input the analysis results for the relevant criteria.

2.2.2. Evaluation of Qualitative Criteria

Based on incidence table, the following AHP algorithm is constructed by VB language of NSDL.

Step 1: Judgment Matrix Construction

When AHP diagram is constructed, judgment matrix to reflect expert’s subjective assessment is made. The judgment matrix may be made by comparison table.

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Table 2. *Meaning of Comparison Values.*

Comparison value	Meaning
1	Equally importance
3	Moderately importance
5	Strongly importance
7	Very strongly importance
9	Extreme importance
2, 4, 6, 8	Intermediate values

Step 2: Calculation of the weight by geometric average.

1) Calculate the product $M_i = \prod_{j=1}^{n} a_{ij}, i = \overline{1,n}$ of the elements of each row of judgment matrix A.

2) Calculate the n[th] square root $\overline{w}_i = \sqrt[n]{M_i}$ of M_i.

3) Calculate the weight by normalizing vector $\overline{W} = [\overline{w}_1, \overline{w}_2, \ldots, \overline{w}_n]^T$.

$$w_i = \frac{\overline{w}_i}{\sum_{j=1}^{n} \overline{w}_j} \tag{2}$$

where $W = [w_1, w_2, \ldots, w_n]^T$ is an eigenvector.

Step 3: Consistency

The validity of the judgment matrix is determined by the *CI* (Consistency Index).

$$CI = \frac{\lambda_{\max} - n}{n-1} \tag{3}$$

The consistency of the judgment matrix is determined by the average random consistency ratio.

If CI doesn't satisfy the following condition, though it is less than 0.1, must check the judgment matrix again.

$$CR = \frac{CI}{RI} \leq 0.1 \sim 0.15 \tag{4}$$

Table 3. *Random Consistency Index.*

n	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
$R.I$	0	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49	1.51	1.53

2.2.3. Evaluation of Quantitative Criteria

The quantitative criteria may be normalized by simple, max/min and sigmoid method according to the user's requirement. The sigmoid transformation method uses the following expression to estimate the importance:

$$\text{Standard deviation } \sigma = \sqrt{\frac{\sum (x - \bar{x})^2}{n-1}} \tag{5}$$

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$$\text{Sigmoid transformation } a_i = \frac{x_i - \bar{x}}{\sigma} \tag{6}$$

The larger the value, the better the case:

$$w_i = \frac{1 - e^{-a_i}}{1 + e^{-a_i}} \tag{7}$$

The lower the value, the better the case:

$$w_i = \frac{1 - e^{a_i}}{1 + e^{a_i}} \tag{8}$$

2.2.4. Evaluation Total Weight

For a given problem, let the criteria be *K* layers and the M_k criteria of the *k-th* layer denotes separately $W_1^{(k)}, W_2^{(k)}, \cdots, W_{M_k}^{(k)}$. The weight of the *j-th* criterion $W_j^{(k)}$ of the *k-th* layer is $w_{j^{(k)}}^{(k)}$. Let the estimate of the alternative X_i for *j-th* criterion $W_j^{(1)}$ of the *1-th* layer (lowest layer) is $x_{j^{(1)}}$. The overall estimate $\overline{x_i}$ of the alternative X_i is

$$\overline{x_i} = \sum_{j^{(k)}=1}^{M_k} \cdots \sum_{j^{(2)}}^{M_2} \sum_{j^{(1)}}^{M_1} w_{j^{(k)}}^{(k)}, \ldots w_{j^{(2)}}^{(2)} w_{j^{(1)}}^{(1)} x_{j^{(1)}} \tag{9}$$

Here, quantitative criteria are inputted by analysis results and normalized by simple method.

3. ASSESSMENT OF STUDENTS' QUALIFICATION USING IAHP

3.1. AHP Structural Modeling

The AHP structure model for students' qualification assessment written in diagram of IAHP is as follows.

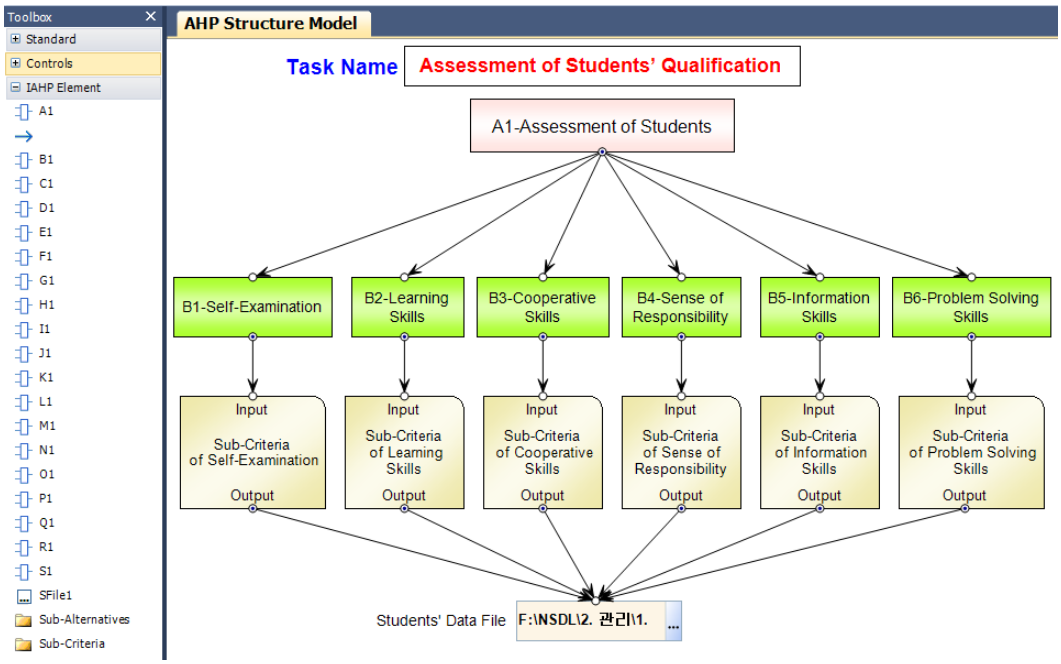

Figure 2. *AHP Structure Model.*

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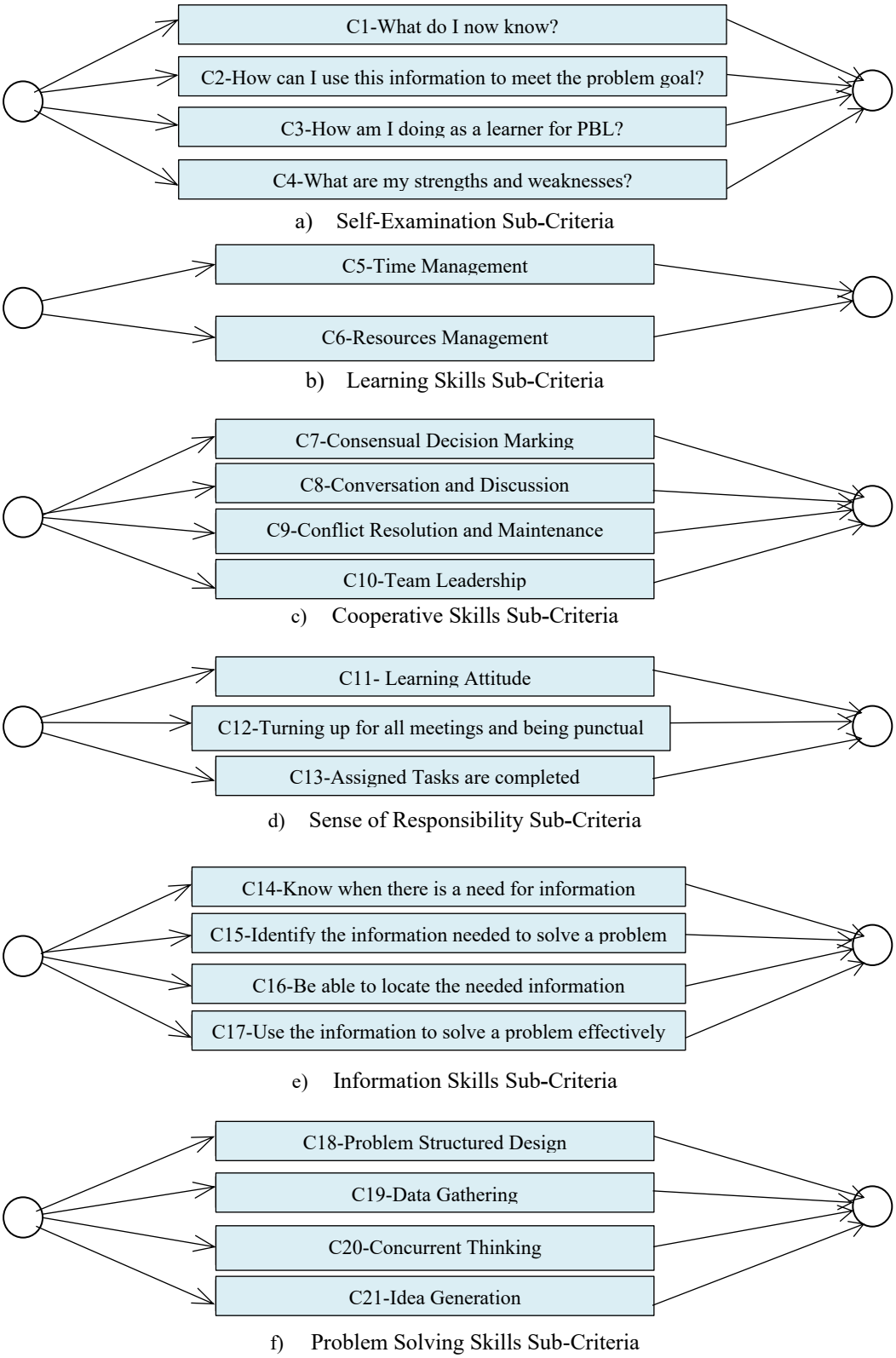

Figure 3. Sub-Criteria Element.

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3.2. Evaluation of Qualitative and Quantitative Criteria

The incidence table corresponding to the AHP Structural model is shown in Table 4.

Table 4. *Incidence table corresponding to the AHP structural model.*

№	A1	B1	B2	B3	B4	B5	B6	C1	C2	C3	…	C20	C21
1	B1	C1	C5	C7	C11	C14	C18	S1	S1	S1	…	S1	S1
2	B2	C2	C6	C8	C12	C15	C19	S2	S2	S2	…	S2	S2
3	B3	C3		C9	C13	C16	C20	S3	S3	S3	…	S3	S3
4	B4	C4		C10		C17	C21	S4	S4	S4	…	S4	S4
5	B5							S5	S5	S5	…	S5	S5
6	B6							S6	S6	S6	…	S6	S6
7								S7	S7	S7	…	S7	S7
8								S8	S8	S8	…	S8	S8
…								…	…	…	…	…	…
35								S35	S35	S35	…	S35	S35
36								S36	S36	S36	…	S36	S36
37								S37	S37	S37	…	S37	S37

The judgment matrix of qualitative criteria are shown as tables.

Table 5. *Judgment matrix for goal A1.*

A1	B1	B2	B3	B4	B5	B6	Weight
B1	1	0.3333333	0.1428571	0.1111111	0.125	0.2	0.0251954
B2	3	1	0.2	0.1428571	0.1666667	0.3333333	0.045783
B3	7	5	1	0.3333333	0.5	3	0.1798516
B4	9	7	3	1	2	5	0.3924806
B5	8	6	2	0.5	1	4	0.2680967
B6	5	3	0.3333333	0.2	0.25	1	0.0885927

Table 6. *Judgment matrix for B1- Self-Examination.*

B1	C1	C2	C3	C4	Weight
C1	1	0.3333333	0.2	0.1428571	0.0550225
C2	3	1	0.3333333	0.2	0.1177864
C3	5	3	1	0.3333333	0.2633784
C4	7	5	3	1	0.5638128

Table 7. *Judgment matrix for B2- Learning Skills.*

B2	C5	C6	Weight
C5	1	3	0.75
C6	0.3333333	1	0.25

Table 8. *Judgment matrix for B3- Cooperative Skills.*

B3	C7	C8	C9	C10	Weight
C7	1	0.2	0.1428571	0.1111111	0.0393486
C8	5	1	0.3333333	0.2	0.1259583
C9	7	3	1	0.3333333	0.2696383
C10	9	5	3	1	0.5650548

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Table 9. *Judgment matrix for B4- Sense of Responsibility.*

B4	C11	C12	C13	Weight
C11	1	3	0.3333333	0.258285
C12	0.3333333	1	0.2	0.1047294
C13	3	5	1	0.6369856
B4	C11	C12	C13	Weight

Table 10. *Judgment matrix for B5- Information Skills.*

B5	C14	C15	C16	C17	Weight
C14	1	0.3333333	0.2	0.1428571	0.0550225
C15	3	1	0.3333333	0.2	0.1177864
C16	5	3	1	0.3333333	0.2633784
C17	7	5	3	1	0.5638128

Table 11. *Judgment matrix for B6- Problem Solving Skills.*

B6	C18	C19	C20	C21	Weight
C18	1	3	5	0.3333333	0.2633784
C19	0.3333333	1	3	0.2	0.1177864
C20	0.2	0.3333333	1	0.1428571	0.0550225
C21	3	5	7	1	0.5638128

The Excel data file for 37 students indicated in SFile is shown in Table 12.

Table 12. *Public assessment marks for 37 students.*

Assessment method		**《Very High: 30, High: 20, Middle: 10, Low: 5》 must be chosen only one mark for all students.**														
№	**Name**	**C1**	**C2**	**C3**	**C4**	**C5**	**C6**	**C7**	**C8**	**C9**	**…**	**C17**	**C18**	**C19**	**C20**	**C21**
1	Cha Chol Ho	30	20	30	30	20	20	30	20	30	…	30	30	30	20	30
2	William	20	30	30	20	20	30	20	30	20	…	20	30	20	30	30
…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…
36	Ri Kum Son g	10	10	10	10	10	10	10	20	10	…	20	5	10	5	10
37	Marie	10	10	10	10	10	10	10	10	10	…	20	5	10	5	10

3.3. Evaluation Total Weight

The results are analyzed from the overall data. The results are as follows.

Table 13. *Summary of Results.*

Goal	**B- Criteria Layer**		**C- Criteria Layer**		**S– Alternative Layer**		**Ranking**
	Criteria	**Weight**	**Criteria**	**Weight**	**Alternatives**	**Weight**	
A1- Assessment of Students'	B1-Self-Examination	0.0252	C1-What do I now know?	0.0014	S13- David	0.0367	1
			C2-How can I use this	0.0030	S7- Köster	0.0345	2

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Qualification			information to meet the problem goal?		S8- K. J. Jon	0.0380	3
			C3-How am I doing as a learner for PBL?	0.0066	S16- Vörös	0.0404	4
					S5- U. I. Ri	0.0364	5
			C4-What are my strengths and weaknesses?	0.0142	S1- C. H. Cha	0.0352	6
					S6- Y. M. Pak	0.0372	7
	B2-Learning Skills	0.0458	C5-Time Management	0.0343	S26- S. K. Jo	0.0371	8
					S2- William	0.0274	9
			C6-Resources Management	0.0114	S32- J. H. Kim	0.0236	10
					S15- J. Y. Ra	0.0208	11
	B3-Cooperative Skills	0.1799	C7-Consensual Decision Making	0.0071	S33- Henry	0.0363	12
					S9- D. H. Ryu1	0.0373	13
			C8-Conversation and Discussion	0.0227	S10- Kare	0.0212	14
					S11- Marcio	0.0242	15
			C9-Conflict Resolution and Maintenance	0.0485	S14- Cha Ming	0.0360	16
					S18- Dzakiyah	0.0172	17
	B4-Sense of Responsibility	0.3925	C10-Team Leadership	0.1016	S17- Karolina	0.0217	18
					S22- S. M. Ju	0.0175	19
			C11- Learning Attitude	0.1014	S25- U. C. Cheo	0.0202	20
			C12-Turning up for all meetings and being punctual	0.0411	S27- Reisig	0.0267	21
					S21- O. C. Choe	0.0207	22
			C13-Assigned Tasks Are Completed	0.2500	S19- Dawid	0.0181	23
					S31-H. S. Kim	0.0308	24
	B5-Information Skills	0.2681	C14-Know when there is a need for information	0.0148	S20- D. H. Ryu	0.0255	25
					S24- John	0.0304	26
			C15-Identify the information needed to solve a given problem	0.0316	S23- J. S. Ri	0.0243	27
					S28- R. H. Kim	0.0363	28
					S4- K. C. Jong	0.0230	29
			C16-Be able to locate the needed information	0.0706	S29- M. S. Kang	0.0186	30
	B6-Problem Solving Skills	0.0886	C17-Use the information to solve the given problem effectively	0.1512	S30- David	0.0218	31
					S3- S. H. Han	0.0362	32
					S12- K. H. Choe	0.0244	33
			C18-Problem Structured Design	0.0233	S35- K. H. Pak	0.0169	34
			C19-Data Gathering	0.0104	S36- Ri Song	0.0169	35
			C20-Concurrent Thinking	0.0049	S34- C. Han	0.0151	36
			C21-Idea Generation	0.0499	S37- Marie	0.0152	37

As shown in the Table 13, IAHP can be solved for AHP problem having so many alternatives.

4. CONCLUSION

In this paper, we have considered about method to assess the students' qualification intuitively and conveniently by

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using an integrated hierarchical analysis tool (IAHP) developed in the network-oriented system description language NSDL environment, which is developed by combining the advantages of Petri nets and object-oriented programming languages.

With the introduction of File Alternative Element (SFile), AHP structural model can be constructed more conveniently, simply and effectively in the case of so many alternatives

Abbreviations

IAHP:	Integrated Analytical Hierarchy Process
NSDL:	Net-oriented System Description Language
VB:	Visual Basic
PBL:	Problem-Based Learning

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Conflicts of Interest

The authors declare no conflicts of interest.

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