Design of Partial Scoring Assessment System for Reinforcement Concrete Design Course

Yu-Hur Chou, Tung-Nan Institute of Technology, Taipei, Taiwan
(yhchou@mail.tnit.edu.tw)

Shang-Hsien Hsieh, National Taiwan University, Taipei, Taiwan
(shhsieh@ntu.edu.tw)

Summary

In the field of Civil Engineering, the content of reinforcement concrete design course (RC course) has complicated design procedures and many difficult specifications to recognize, so most of the students regard the RC course a tough course, and teachers very often find the class time insufficient. Also, teachers of the RC course usually spend a lot of time in organizing the examinations for handling tedious calculations and complicated logical reasoning. Furthermore, correcting examination papers with partial scoring takes even more time of the teacher's. Therefore, the objective of this research is to design and develop a partial scoring assessment system to meet the needs in engineering design courses, such as the RC course. This assessment system can generate test items with variable parameters. It also supports inference diagnosis on the examinee's misconceptions and gives partial scores in grading the examination. In this research, the example test subject is the analysis of rectangular reinforced concrete beam with single layer steel bars.

1 Introduction

Learning and teaching engineering courses at university level is not an easy job, since the knowledge structure on engineering is complicated and may not be well defined. Therefore, it becomes challenging or probably inappropriate to use traditional test formats, such as multiple-choice, fill-in-blanks, or short essay questions for assessing students' achievement. Most traditional tests are dichotomously scoring that fail to detect the thinking process of how students solve the problems. Instead, they only reflect students' responses in the last step. Such a traditional test format ignores the importance of student's problem-solving performance in every step, and neither provides the analysis of students' misconceptions in the problem-solving process. In contrast to the dichotomously scoring, the polytonality scoring instruments are able to provide more accurate and valid assessment in engineering courses (Muraki, 1992). Therefore, most university engineering faculty favors the polytonality tests. However, there are some limitations on using the polytonality tests. Firstly, they have to be organized manually, and their preparation is more time-consuming. Secondly, it is still difficult for teachers to describe students' misconceptions due to the limitation of teachers' memory capacity. Therefore, the purpose of this research is to design and develop a partial scoring assessment system to meet the needs in engineering courses. We adopt three useful designs to complete the system functions. First, the concept mapping technique is used to support a user environment for the examinee to describe the process and report the corresponding calculated result for each step of problem solving. Second, a rule-based Petri-net module is applied to represent the logical structure of correct answers. Third, the fuzzy mapping logic is used to calculate the score and diagnose students' misconceptions.

The proposed assessment system includes the following functions and features:

(1) Test items of the system are managed in a parameterized style and can be generated dynamically, so that the numeric values in the test items can be changed when the test is in

process. This can prevent students from memorizing the answers. The test items are selected automatically by following the adjustment of test concepts.

(2) The concept mapping is used for representing the examinee's answer. Concept mapping is the technique of drawing a concept map to illustrate the structure of knowledge. There are some applications of the concept mapping techniques in education, such as the assessment and diagnosis of learning effect, the analysis of the learning path, and the representation of knowledge (Anderson, 1995). Examinee must draw the concept map and answer the calculation results for the test subject. By using the concept mapping technique, it is easy to obtain enough information to investigate examinee's misunderstandings and to inference for diagnosis (Laffey and Singer, 1997).

(3) The Petri-Nets have been developed to describe information-processing systems that are characterized as being concurrent, asynchronous, distributed, parallel and stochastic (Peterson, 1981; Molloy, 1989). We find that the Petri-Nets is suitable for creating dynamical test items, and has many advantages for constructing the logical structure of the correct answers.

(4) By using the fuzzy mapping logic and Goldsmith's closeness index (Chen et al., 2001 and Goldsmith et al., 1991), a calculating logic is developed for making the reasonable partial scoring.

2 System Architecture

The proposed assessment system is developed on the Windows platform using Visual Basic. It uses MS Access as the database system. The system architecture of the system is shown in Fig. 1. It has four sub-systems (modules): Test Generator, Concept-Mapping Reply sub-system, Answering Evaluator, and Diagnostic Evaluator.

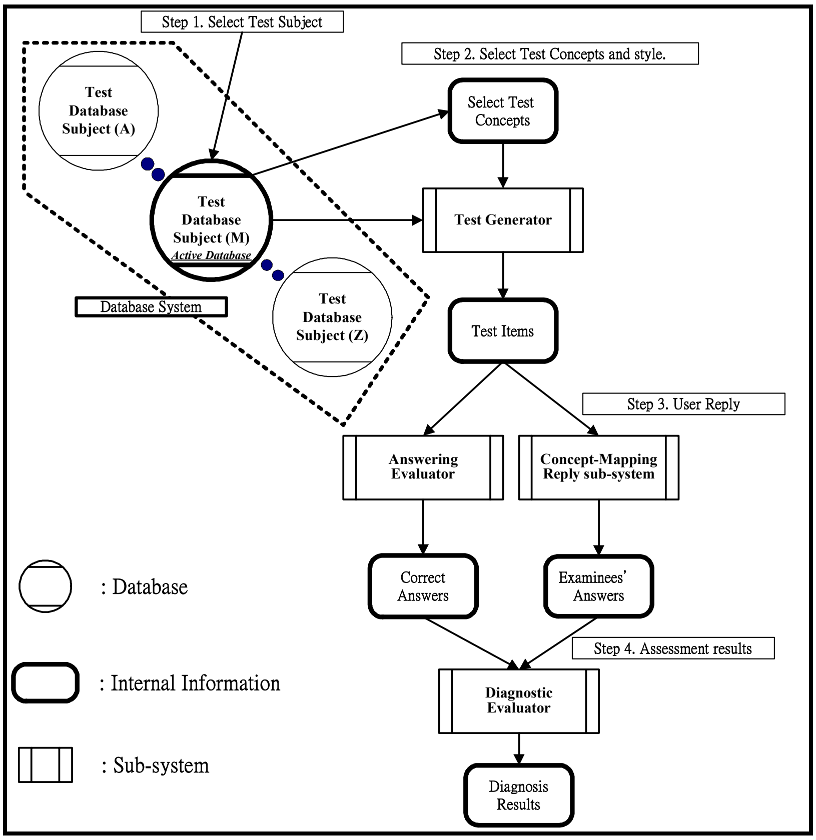

Figure 1. System Architecture

Test Generator (TG): This module builds test items automatically by following the selecting test concepts and formats. The values of the variables associated with the test items are generated randomly. Therefore, the same kind of test problem will be shown with different variable values for different tests. The answering evaluator will calculate the correct answers accordingly. The diagnostic evaluator will then trace the processes of the user's operations and identify the examinee's misconceptions if there are any.
Concept-Mapping Reply Sub-system (CMRS): This module employs the concept mapping approach to provide a reply environment for the examinee to report his or her problem solving process and step-by-step solutions. Examinee is first asked to draw the concept map and provide the calculation results for each calculating step for the test subject. CMRS also records all examinee's operations for further evaluation.
Answering Evaluator (AE): This module produces the correct answers for the test problems.
Diagnostic Evaluator (DG): This module diagnoses users' problem-solving skills.
In addition, the operations of the assessment system consist of four steps: (1) select the test subject, (2) select the concepts and test formats, (3) receive examinee's reply, and (4) display the diagnostic results.

3 System Analysis and Design

For the convenience of explanation, we select the analysis of rectangular reinforced concrete beam with single layer steel bars) as an example test subject here. The designed procedures are described as follow:

3.1 Defining subject concepts

There are 21 major knowledge concepts for the example subject (see Table 1). These concepts are identified and proposed by several colleague experts of the first author.

3.2 Defining subject calculations

There are 22 calculations (see Table 2) involved in solving the problem of the example subject.

3.3 Evaluation between concepts and calculations

In this step, we develop relationships between calculations and concepts. Within the correlative evaluation table (see Table 3), e_{ij} is the related value which equals 1 if Q_i and C_j are related or 0 if they are not related. All of the information in Table 3 are created and saved in the database system.

Table 1. Major concepts in the example subject

Item	Concept name	Item	Concept name
1	Required Resisting Strength	12	Parameter of Equivalent Stress Block
2	Stress-Strain Diagram (Reinforcement)	13	Equivalent Stress Block
3	Modulus of Elasticity (Reinforcement)	14	Concept of Under reinforced Case
4	No. Of Reinforcing Steel	15	Concept of Over reinforced Case
5	Area of Reinforcing Steel	16	Concept of Balanced Case
6	Modulus of Elasticity (Concrete)	17	Concept of Proportional Ratio
7	Ultimate Strain of Concrete	18	Equilibrium of Forces
8	Compressive Strength of Concrete	19	Solution of Linear Equations
9	Capacity Reduction Factor	20	Central of Cross-Section
10	Nominal Resisting Strength	21	Solution of second order equation
11	Designed Resisting Strength		

Table 2. Calculations for problem solving in the example subject

Item	Calculation Name	Item	Calculation Name
1	Balanced Depth of Neutral Axis	12	Depth of Equivalent Stress Block
2	Modulus of Elasticity (Concrete)	13	Depth of Neutral Axis (Balance)
3	Area of Bar	14	Stress of Reinforcement (Balance)
4	Depth of Equivalent Stress Block (Balance)	15	Stress of Reinforcement (Under reinforcement)
5	Parameter of Equivalent Stress Block	16	Nominal Resisting Moment (Tension)
6	Under reinforced Case	17	Nominal Resisting Moment (Compression)
7	Area of Bar (Balance)	18	Total Tensile Force
8	Balanced Reinforcement Ratio	19	Depth of Neutral Axis (Under reinforcement)
9	Over reinforced Case	20	Depth of Neutral Axis (Over reinforcement)
10	Balanced Case	21	Stress of Reinforcement (Over reinforcement)
11	Total Compressive Force	22	Ultimate Resisting Moment

Table 3. Illustration of relationship evaluation between concepts and calculations

Relationship between Q_i and C_j		Concept C_j				
		C_1	C_2	C_3	…….	C_n
Calculation Item Q_i	Q_1	e_{11}	e_{12}	e_{13}	…….	e_{1n}
	Q_2	e_{21}	e_{22}	e_{23}	…….	e_{2n}
	Q_3	e_{31}	e_{32}	e_{33}	…….	e_{3n}
	….	….	….	….	…….	….
	Q_m	e_{m1}	e_{m2}	e_{m3}	…….	e_{mn}

3.4 Construct the logical structure of correct answer

In this research, we propose a rule-based Petri-Net model to construct the logical structure of answers for the selected example subject. The Petri-Net model contains four sets, which are: transition (calculating functions), place (parameters), input arcs, and output arcs. Figure 2 shows an independent unit of the Rule-based Petri-Net. The calculating function is fired to compute the output parameter, i.e., the total tensile force (T) in this case, after all values of the input parameters, i.e., the area of reinforced bar (A_s) and the stress of reinforcement (f_s), are known. It should be noted that the calculating function can only be fired once.

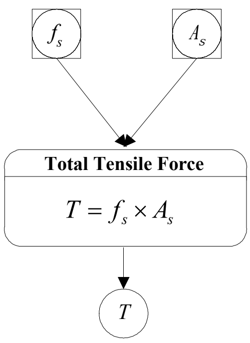

Figure 2. An independent unit of the rule-based Petri-Net

3.5 Partial scoring function

The system uses two mechanisms to assess the score of the examinee. The first mechanism applies Goldsmith's closeness index to measure similarity between the correct concept map and the examinee's concept map. The second mechanism evaluates the correctness ratio of calculations. The final score is calculated using the following formula:

$$Score = WC \times GCI + WS \times CRC \text{ ------------------------------- } (1)$$

where

Score: Final score.

WC: Weighting coefficient for GCI, ranging from 0 to 1.

GCI: The value of Goldsmith's Closeness Index.

WS: Weighting coefficient for CRC (= *1-WC*).

CRC: The value of Correctness Ratio of Calculations. It is computed based on the following formula:

$$CRC = \Sigma(Pi \times Di) / \Sigma Di \quad (i = 1 \sim m) \text{ -------------------- } (2)$$

where

Pi: The score value of each calculation (0 or 1). The system takes into account that mistakes made in the previous calculations may propagate to the subsequent calculations. Therefore, as long as the calculation (instead of the solution) performed by the examinee is correct, *Pi* is given the value of 1. Otherwise, the value of *Pi* is 0.

Di: The level of difficulty for each calculation, ranging from 1 (easy) to 9 (hard).

m: The number of calculations within a test item.

3.6 Misconception evaluation

Equation 1 gives the examinee's final score for each test. The examinee's misconceptions can be accessed using the table of evaluation between concepts and calculations (i.e., Table 3).

4 System Demonstrations

Figure 3 shows the system's first screen page which asks the user to select the subject area for examination. After the subject area is selected, the user should select the knowledge concepts to be included in the test and the desired type of the test (see Fig. 4).

Figure 3. Select a test subject

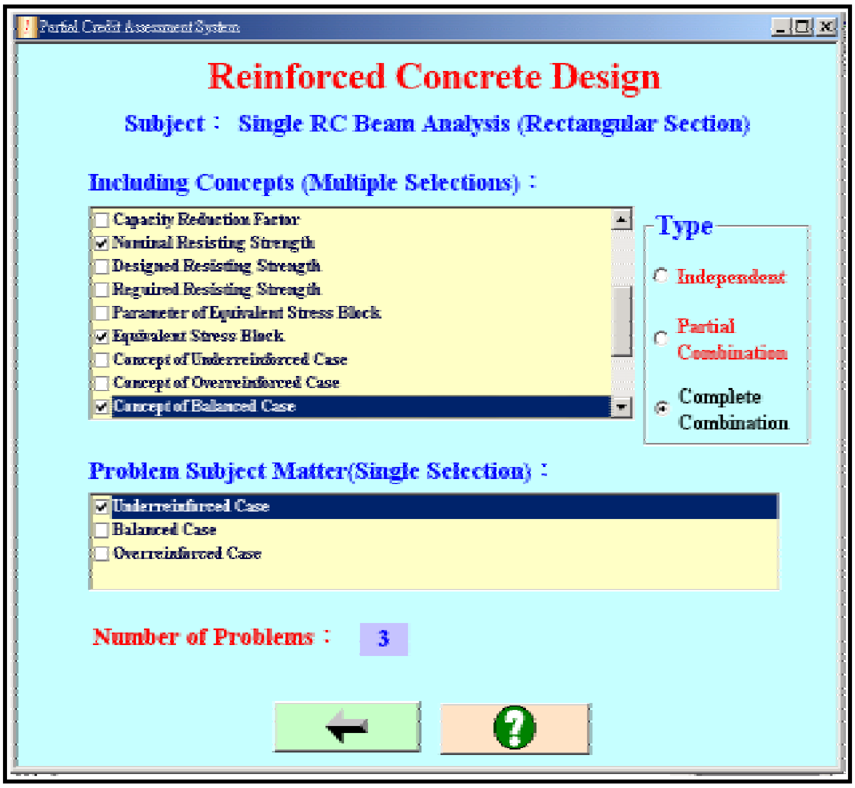

Figure 4. Select concepts to be included in the test and the type of the test

The test generator then composes the test items (see Fig. 5) according to the selected subject, test concept and format. The values of given parameters are assigned randomly by the system. The answer evaluator generates the correct answers (see Fig. 6). It shows the correct calculating procedures and the correct answer for each calculation step by step.

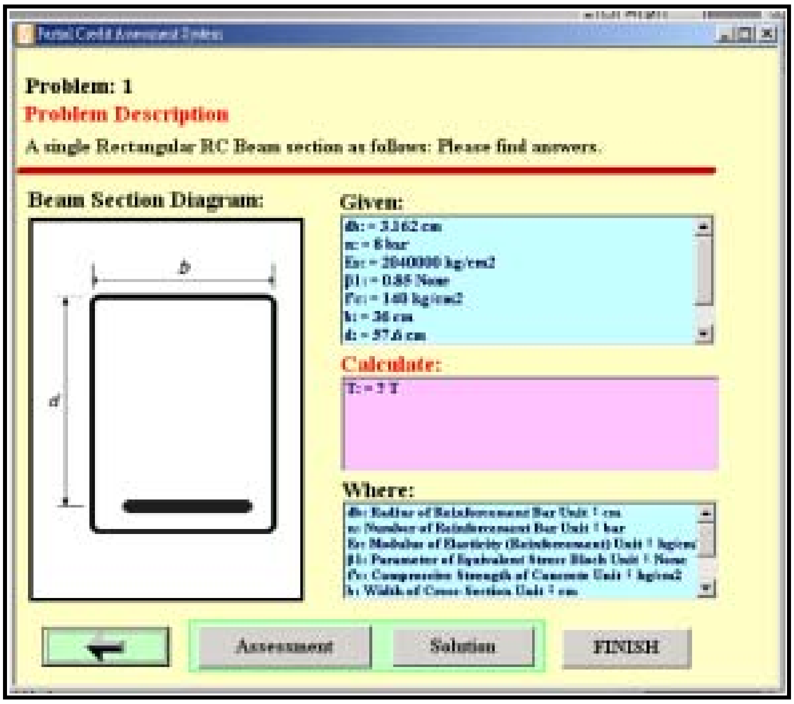

Figure 5. Problem description

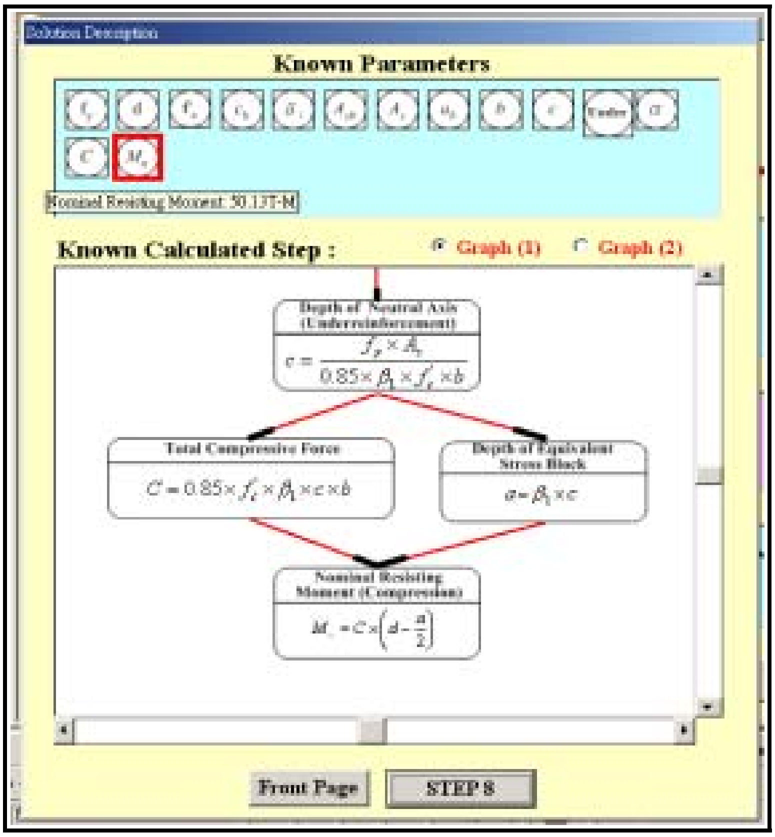

Figure 6. Answer evaluator

Once taking the test, the examinee first draws his or her concept mapping answers in the CMRS sub-system (see Fig. 7). The examinee then follows the problem-solving flow of the drawn concept map and keys in the step-by-step solutions. Figure 8 shows the assessment results provided by the system, including the problem description of the test item, the correct answers and problem-solving procedures, the examinee's answers and problem-solving procedures.The scoring instruction shown in Fig. 9 explains how the final score is added up. The results of the misconception evaluation provided by the system are shown in Fig. 10.

5 Conclusions

In this research, we have developed a partial scoring assessment system. This assessment system supports dynamic generation of test items. The values of the test variables are generated randomly but in a consistent manner. This means that the same parameterized test problem is automatically assigned different variable values for different tests to prevent students from memorizing the answers. We also propose a Rule-based Petri-Net model for building the logical structure of the correct answers. This logical structure works nicely with both the dynamic problem pattern and random parameters. In addition, this system adopts a concept-mapping approach to acquire enough information about the examinee's problem-solving ability. The information is then used for misconception evaluation and score assessment using the presented partial scoring strategy. It is believed that this kind of partial scoring systems can be helpful in assisting the teaching of many engineering design courses that deal with logical reasoning of design procedures.

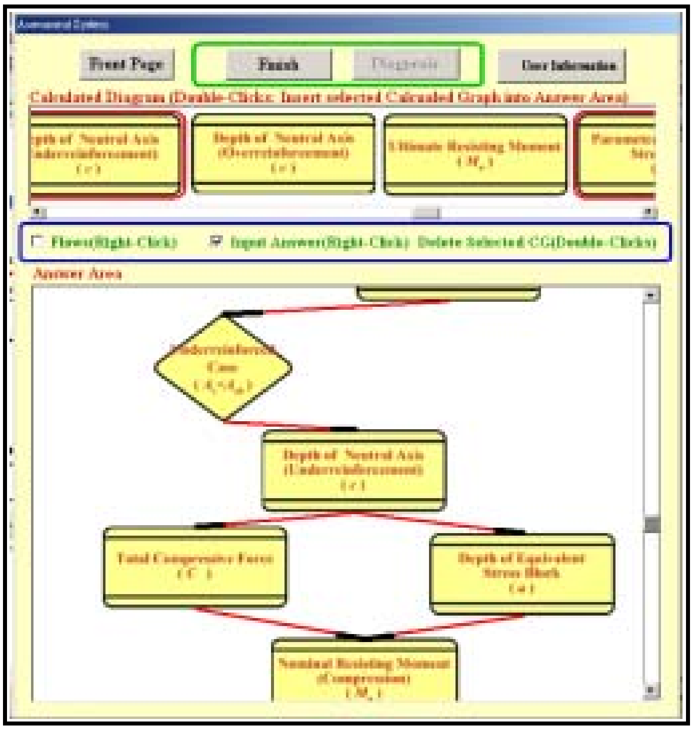

Figure 7. The CMRS sub-system

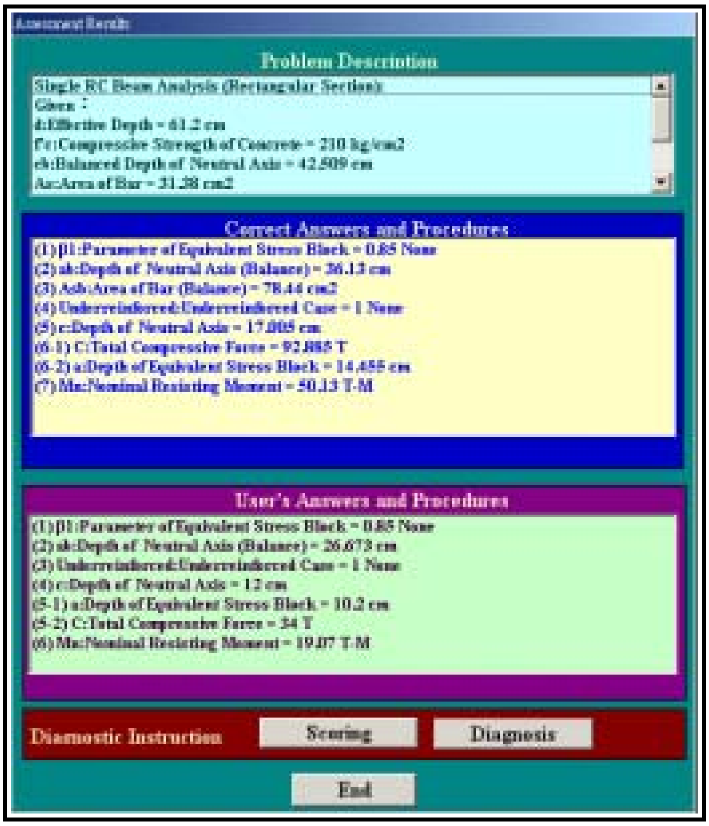

Figure 8. Assessment results

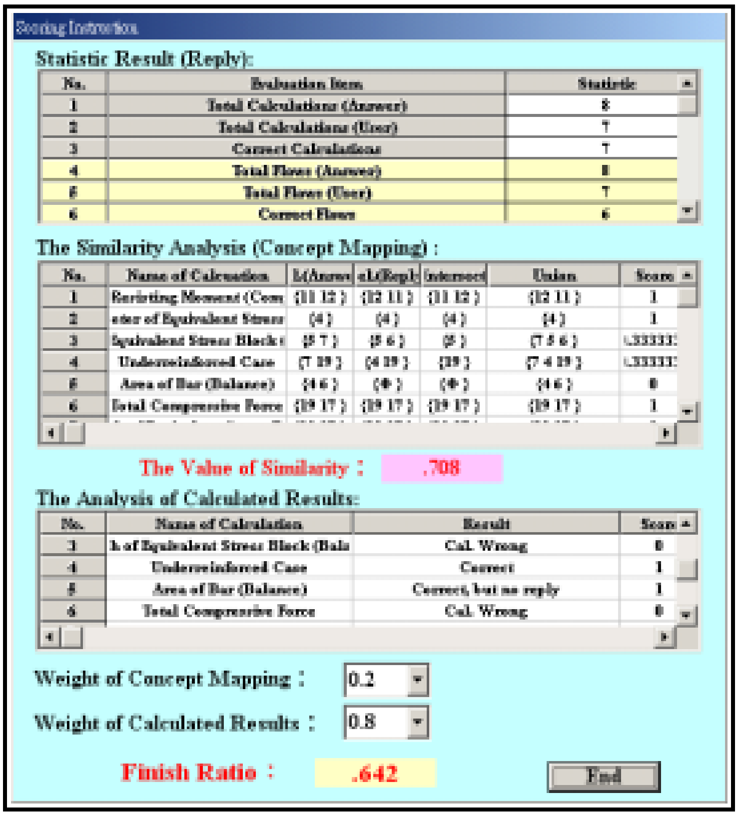

Figure 9. Scoring instruction

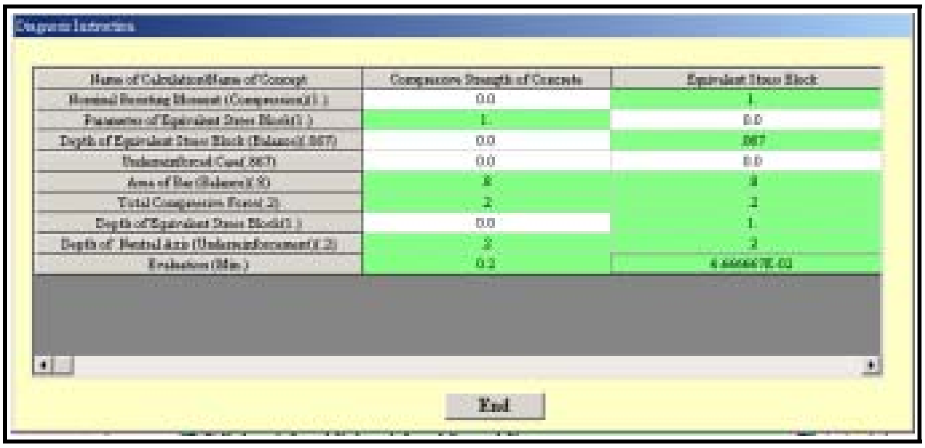

Figure 11. Misconception evaluation

6 Acknowledgements

The authors would like to thank National Science Council, R.O.C. for funding this study under the grant number NSC-91-2552-S-002-005.

7 References

Anderson, J.R., (1995), Cognitive Psychology and its Implication. New York: Freeman and Company.

Chen, S., Lin, S., and Chang, K., (2001), *Attributed Concept Maps: Fuzzy Integration and Assessment*, IEEE Trans. on Systems, Man, and Cybernetics. Part B: Cybernetics, 31(5), 842-852.

Goldsmith, T., Johnson, P., and Acton, W., (1991), *Assessing structural knowledge*, Journal of Educational Psychology, 86, 88-96.

Laffey, J. M. and Singer, J. (1997), *Using Mapping for Cognitive Assessment in Project-based Science*, Journal of Interactive Learning Research, 8(3-4), 363-387.

Molloy, M. K., (1989), *Petri Net Modeling – The Past, the Present, and the Future*, Proceedings of the Third International Workshop on Petri Nets and Performance Models, Dec. 11-13, Kyoto, Japan.

Muraki, E., (1992), *A Generalized Partial Credit Model: Application of an EM Algorithm*, Applied Psychological Measurement, 16(2), 159-176.

Nawy, Ed., (1996), Reinforced Concrete: A Fundamental Approach, Englewood Cliffs, New Jersey: Prentice Hall.

Peterson, J. L., (1981), Petri Net Theory and the Modeling of Systems, Englewood Cliffs: NJ: Prentice Hall.