The Application of Cognitive Diagnostic Model for Achievement Profile Analysis and Score Report

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I. Necessity of Study

- As the significance of assessments in learning is highlighted, the analysis and reporting of assessment results should go beyond simple identification of the academic achievements and aim to provide information useful for helping the learning and growth of students, as well as information on the mastery of individual students’ detailed cognitive attributes.

- Instead of interpreting the results of the assessment using the total test score or the rank, providing the profile of the academic achievement, which indicates the level of mastery of each cognitive attribute, will aid the understanding of students, teachers and parents of the results of the assessment. This will lead to easier learning planning and contribute to efficient educational policy-making.

- In order to develop measures to significantly improve the analysis and the reporting of the results of the National Assessment of Educational Achievement (NAEA), there is a need to apply the Cognitive Diagnostic Model, which is gaining attention in the area of the educational assessment.

II. Purpose of Study

- Provide the academic achievement level of individual students in the form of a detailed profile by applying the latest assessment theory, the Cognitive Diagnostic Model, to NAEA.

III. Contents of Study

- Explore the Cognitive Diagnostic Model that is optimal for analysis of NAEA

- Define detailed guidelines and process for Q-matrix construction, which is a key to the successful application of the Cognitive Diagnostic Model

- Identify the characteristics of the academic achievement profile of Korean students in Korean Language and Mathematics using the Cognitive Diagnostic Model

- Propose the scheme for advanced and enhanced assessment result report to provide useful information in order to give detailed and personalized feedback for each student and facilitate their academic development

IV. Results of Study

- Evaluation of an Appropriate Cognitive Diagnostic Model for NAEA
  - As NAEA includes both multiple-choice and constructed-response items, this study aimed to identify the Cognitive Diagnostic Model appropriate for processing the polytomous score of the constructed-response items. In addition, the model had to be able to process the large-scale data of over 600,000 students.
The model appropriate for NAEA was explored by comparing the performance of both the Fusion and the DINA models, the most widely used Cognitive Diagnostic Models in previous studies. Through a comparison of two models (Fusion vs. DINA), the Fusion model was identified as the most appropriate one for the analysis of NAEA. In particular, the Fusion model was superior when the mastery level of cognitive attributes of individual students, which was estimated using the cognitive diagnostic model, was categorized into more than two levels (e.g. high, medium, and low) rather than only two levels (e.g. mastery and non-mastery).

**Establishment of Detailed Guidelines and Process for Q-matrix Construction**

- Cognitive attributes collectively refer to the ability, the skills, the knowledge or the cognitive process necessary to correctly answer the item. “Q-matrix” is a \((n \times p)\) matrix connecting \(n\) number of items and \(p\) number of cognitive attributes.

- The Q-matrix is developed from domain experts’ agreement. There are no general guidelines or standardized process for Q-matrix development. This study aims to provide reference guidelines for developing and verifying Q-matrix.
Results of Analysis of Academic Achievement Profile Using Cognitive Diagnostic Model

By applying the Cognitive Diagnostic Model, the characteristics of the academic achievement profiles of Korean students in Korean Language and Mathematics were analyzed.

In addition to the characteristics of the academic achievement profile by school level, the characteristics by gender and region, which are the critical factors for achievement gaps, were analyzed. As social interests and needs for educational support in relation to multicultural families have recently increased, the characteristics of students from multicultural backgrounds were also analyzed.

The mastery level of students in relation to 14 cognitive attributes of Korean Language and 13 cognitive attributes of Mathematics were featureless at elementary, middle and high schools, while there was a large gap in the specific cognitive attribute. For example, students in grade 6 in elementary schools, students in grade 3 in middle schools, and students in grade 2 in high schools showed mastery percentage of 73%, 67%, and 56%, respectively, for the cognitive attributes of “understanding implications and meanings” showing a downward trend as school level increases. Identifying the characteristics of the academic achievement profile of students in this way can provide efficient support solutions for improving academic achievement.

As International marriage, influx of foreign workers, etc. increase, the number of students from Korea’s multi-cultural families is expected to be higher; therefore, identifying the characteristics of their academic achievement is significant in reinforcing Korea’s basic achievement.

It seemed that students from multi-cultural backgrounds and students from ordinary family showed the smaller gap in the mastery of cognitive attributes in Korean Language and Mathematics at higher school levels, which indicates that students from international marriage have narrowed the gap with students from ordinary family. Midway entering students and North Korean refugees suffered more serious underachievement at higher school levels. Therefore, supporting for midway entering students and North Korean refugees is the most urgent.
According to the analysis on the causal relation between the educational context variables and the mastery of cognitive attributes using the Structural Equation Model targeting students with below-basic achievement, the family background, the level of adaptation to school life, and the school climate positively and indirectly affected the mastery of cognitive attributes in Korean Language and Mathematics through the medium of the affective characteristics for subjects. The affective characteristics for subjects positively and directly affected the mastery of cognitive attributes in Korean Language and Mathematics.

The results of this analysis indicate that a gap in academic achievements can be caused by background factors. In this sense, poor basic academic proficiency should not be the only reason for underachievement, and various factors other than subject-related teaching and learning should be focused on.
Academic Achievement Profiles of Korean Language and Mathematics

- Assessment Result Report based on Cognitive Diagnostic Model
  - The assessment result report based on the Cognitive Diagnostic Model is useful, as it directly shows what a student can do and how much a student knows rather than displaying a total test score or a rank. In addition, as the report provides feedback about the cognitive strengths and weaknesses of learners, it can be used for the development of a learning strategy that is customized for individual students.
  - The new scheme for assessment result report, which can effectively highlight the strengths of the cognitive diagnostic model, was studied, and the assessment result report for individual students is suggested as <Figure 2>.

Providing the online result reports for teachers in addition to the assessment result reports for individual students → enabling the development of the learning path according to the mastery level of cognitive attributes of students (three levels of high, medium, and low) as <Figure 3> shows (Teachers can separately teach cognitive attributes by student’s mastery level, but it would be effective to interconnect cognitive attributes that are similar or belong to the same cognitive area.)
V. Policy Implications

◈ Operation of differentiated Support Schemes depending on the Cause of Underachievement

- The relation between the educational context variables and the mastery level of cognitive attributes was investigated using the Structural Equation Model, targeting students with below-basic proficiency. As a result, the family background, adaptation to school life and school climate and the affective characteristics for subjects (efficacy, interests in subjects, and value of subjects) positively affected the mastery of cognitive attributes.

- In order to effectively reduce underachievement, diverse causes of underachievement by individual students should be identified, and customized solutions should be provided.
  - If the family background has caused underachievement (such as lack of conversation with family and lack of intimacy within family), parent counseling services should be provided to build a partnership between homes and schools that will improve the basic academic achievement of students.
  - If students have difficulty in school life due to conflicts with peers and poor relations with teachers, plan to enable the students to enjoy learning at schools should be developed, including relationship-building with teachers and support for a healthy school life.

◈ Improvement of Confidence, Interests and Value Awareness on Subjects

- According to the analysis using the Structural Equation Model, the development of a positive affective attitude toward subjects (efficacy, interests in subjects, and values of subjects) positively affected the mastery of cognitive attributes.

- The basic academic achievement of students can be effectively improved by using diverse strategies to improve the affective attitude of students rather than focusing only on subject-related learning.
In order to increase interest in the subjects, the contextual and situational relevance of the learning contents to real life should be considered.

Diverse learning materials, problem-solving assignments, and experiential learning should be provided with a variety of interesting activities.

Positive feedback is critical to improve the efficacy of students. Rather than comparing with peers and focusing on students’ ranking, students should be reminded of improvements in their own achievement growth over time and be encouraged to gain self-efficacy through the assessment.

**Development of the Schemes for Cooperative Learning by Level of Mastery of Cognitive Attributes**

- By matching students who are complementary in terms of their level of mastery of cognitive attributes, they can be encouraged to learn from each other.
- Teachers serve as facilitators and coordinators for the cooperative learning of students.
- In the illustration as Table 1 for grade 6 at elementary school, student A and student B can help each other, as they are at a high level for ‘arithmetic operation’ while they have different levels in terms of ‘understanding of principles and rules’.
- Strengths of low-performing students should be fully utilized to give them a positive attitude toward learning, and repeated learning with peers should be adopted to increase opportunities to gain knowledge and skills.

### Table 1 Illustration of the Cooperative Learning Material by Level of Mastery of Cognitive Attributes of Mathematics for Grade 6, Primary School

<table>
<thead>
<tr>
<th>Students</th>
<th>Cognitive Attributes of Mathematics for Grade 6, Elementary School</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Arithmetic Operation</td>
</tr>
<tr>
<td>A</td>
<td>High</td>
</tr>
<tr>
<td>B</td>
<td>Low</td>
</tr>
</tbody>
</table>

Instead of emphasizing the weaknesses of students, encouraging them to help peers in their strong areas is a more effective way of helping them improve confidence and motivation.

**Development of Customized Learning Support Schemes according to Various Types of Multicultural Background**

- As the number of students from multi-cultural backgrounds will gradually rise due to increases in the number of international marriages and foreign workers, identifying their challenges in academic
achievement caused by language and cultural differences is a meaningful part of improving the basic academic achievement in Korea.

- There is a need to develop schemes to systematically provide customized learning support by analyzing the different needs of each type of multi-cultural background.
  - According to the analysis of the levels of mastery of cognitive attributes in Korean Language and Mathematics, among the students from multi-cultural families in Korea there was an urgent need to support midway entry students and North Korean refugees.
  - Metropolitan and Provincial Offices of Education can identify the strengths and weaknesses of schools by analyzing the characteristics of the academic achievement of schools in their coverage, and can provide opportunities for cooperative learning among schools and regions.

- Development of the System for Providing the Online Assessment Result Report
  - In order to overcome the limitations of providing the assessment results report through paper, schemes to additionally build the online assessment result service system with diverse media coverage should be adopted.
  - As online data can be accumulated, it can be useful for achievement history management. The mid-to-long-term perspective should be adopted to develop the assessment result reporting system so that, for example, a student can monitor his or her academic progress by comparing the achievement at grade 3, middle school with the achievement at grade 6, elementary school.

VI. Expected Benefits

- Identify characteristics of academic achievement of all students at elementary, middle, and high schools; provide customized learning support based on the results; and promote the academic achievement of individual students

- Narrow the educational achievement gap between students by guaranteeing the basic academic achievement of all students at all schools; minimize the accumulation of learning deficits; and ensure equal learning opportunities

- Provide customized learner-centered feedback
  - Enable to set up learning path tailored to individual based on the information on the mastery level of cognitive attributes for individual students
  - Facilitate the self-directed learning of students

- Enable policy-making for specialized and effective educational support
  - Operate differentiated support measures by school level, gender and region
  - Develop the schemes to support academic achievement by providing positive educational environment instead of focusing on the subject-related learning.