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# Developing A Framework for Performance Assessment in Science Education

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**ABSTRACT**

The purpose of this study is to develop a Framework for Performance Assessment in Science Education(F-PASE). Science educators in the past have paid more attention to science curriculum and teaching strategies than assessment. In recent years, attention has turned toward performance assessment which addresses the concerns of science curriculum and instruction, and which is consistent with goals of science education at various levels of interests. Science educators are trying to do performance assessment, yet they don't have a framework that is highly qualified in terms of science educational objectives for the future, and advantages of performance assessment. We, therefore, have developed a framework for performance assessment in science education, which may be useful for science teachers to understand and assess their students' abilities. We have extracted seven domains covering students' various abilities as the important objectives of science performance assessment and grouped them into three categories: General, Science specific, and Intermediate abilities. And we developed a F-PASE with a three dimensional solid figured structure, and illustrated it as the configuration of a com. F-PASE is useful for science teachers to develop and select a science performance assessment as well as have a more advanced understanding of their students' abilities. It is a creative and novel assessment framework in terms of structure, configuration, functions and meanings. It also suggests a new vision of an assessment framework in science education.

**Key words**: science education goals, performance assessment, objectives framework

## I. Introduction

Assessment is an integral part of science education (Glattorn, 1998). That is, all teachers are concerned with what and how their students are learning and doing, and must do something for keeping track of students' progress. Despite the reality that educators need a better method for assessing the progress of students' learning and their abilities, few guidelines have been developed for this. This has resulted in educators' reliance on standardized testing, which usually employs multiple choice or mathematical problem solving formats. While it may be true that most standardized tests adequately assess students' understanding of scientific knowledge, unfortunately it does not serve well to assess a certain type of students' abilities, such as use of process skills and problem solving strategies.

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Assessment in the Korean science education setting paid much attention in the past to a kind of high stakes assessment as standardized test of multiple choice items, but recently, many attempts about alternative assessments, especially performance assessment, are being made all over the nation.

Based on the theoretical backgrounds of constructivism, cognitive psychology and motivational psychology, the value of performance assessment is confirmed in science education (Phillips, 1997; Roth, 1995; Driver & Bell, 1986; Resnick, 1989; Glaser, 1984; Baron, 1991). Performance assessment involves not only the methodology of unifying teaching, learning and assessment, but also the intermediate area which lies between actual classroom experience and theories (Baron & Boschee, 1995; Berk, 1986; Champagne *et al.*, 1990; Wiggins, 1993). However, it is hard to administrate a science performance assessment in practice in concord with theoretical perspectives (Lim *et al.*, 1999; Kim,Y, 1998). Here, a framework is needed to connect these theoretical backgrounds with their practices in the actual science classroom.

The purpose of this study is to develop a framework for performance assessment in science education(F-PASE) which may be useful for science teachers to understand and assess their students' variable abilities. It will help teachers, students, parents, any other educational staffs and authorities have an agreement on the procedures and expected results of performance assessment in science education.

# Ⅱ. Rationale for the Study

## 1. Framework for performance assessment in science education(F-PASE) based on constructivism, cognitive psychology and motivational psychology

The development of F-PASE, as viewed through three perspectives, makes three important points. First, there is a need to recognize the active, rather than passive, nature of students' learning. Second, an instruction must provide information for the process of students' knowledge construction as well as adapt to developmental progress in students' learning. Third, an assessment must involve monitoring and implementing of feedback for students' learning processes and abilities.

## 2. Problems on applying previous assessment framework to performance assessment in science education

The previous assessment framework is used for two purposes in science education. One is to diagnose a teaching-learning interaction, and to get feedback an educational aspect, for example, Bloom's or Klopfer's taxonomy, which has two dimensions, content and behavior (Kim *et al.*, 1991). The content dimension could be designated as the one for scientific domains such as scientific knowledge and attitudes. The other would be for making items of large-scale examinations administered nation-wide, such as APU's(Assessment of Performance Unit's), which have three dimensions(three axes) of scientific knowledge, science process skill and context(Kim *et al.*, 1991).

Both have views of behavioral psychology and quantitative evaluation with psychometry. Also, they pursue an an analytic aspect of assessment. However, F-PASE is completely different from the previous frameworks mentioned above in terms of the perspectives it is based on. That is, F-PASE has a learning view of a cognitive psychology-and qualitative assessment-base. Also, it pursues a holistic aspect of assessment. Hence, the unrevised previous framework cannot be adopted any more, because it pursues some different objectives.

### 3. Characteristics of the society and human beings in the future.

Mach literature has said that the characteristics of future society could be predicted as informationalization, globalization, openness, diversification, self-determination (Kim, E., 2000; Kim, J., 1999; Doll Jr., 1993; Toffler, 1986; Toffler, 1998). Thus, the characteristics of human beings which are appropriated to future society can be identified to be higher thinking(such as critique, analysis, synthesis, assessment), creative thinking, self-determination, communication, value-oriented determination, knowledge applying, information collecting and using of information -communication -technology(ICT).

The domains of F-PASE reflect these abilities and they have been developed according to them.

## Ⅲ. Research Methods and Procedures

We have continuously conducted literature reviews and team discussions about science education goals for the future, the advantages of performance assessment, and the need of a new framework for performance assessment in science education. In the team discussion, the abilities required in the future have been discussed as well as the characteristics of society and human beings, and the domains of F-PASE have been extracted from these.

We have discussed characteristics of performance assessment and analyzed previous assessment frameworks for developing F-PASE. As an analysis of previous assessment framework, we have divided them between 2-dimension and 3-dimension frameworks. We have chosen Bloom's, Klopfer's, and The Consultation for Science Education Improvement's in 2-D framework, and APU's, Korean College Scholastic Ability Test's have been chosen in 3-D. We have analysed and compared them with F-PASE. The criteria of analysis and comparison are concept of assessment framework, period of appearance and use, condition of age, perspective of truth, philosophical background, view of knowledge, learning view, view of learner, view of teacher, role of textbook, view of assessment, view of test, goal of assessment, domains considered in assessment framework, dimension and form of framework, characteristics of framework, usable assessment methods.

Based on above discussions and analysis results, we have developed F-PASE. The detailed steps are as follows: We have extracted 7 assessment domains and their subordinate components for F-PASE. And they are categorized in 3 groups according to the extent of their relevance with the nature of science. We have also developed F-PASE shape like a cone, which has directions, up-down and center-edge. Finally, we have a conclusion about its significance and suggested this framework be applied to science education in Korea.

Our Research procedure is presented in [Fig. 1].

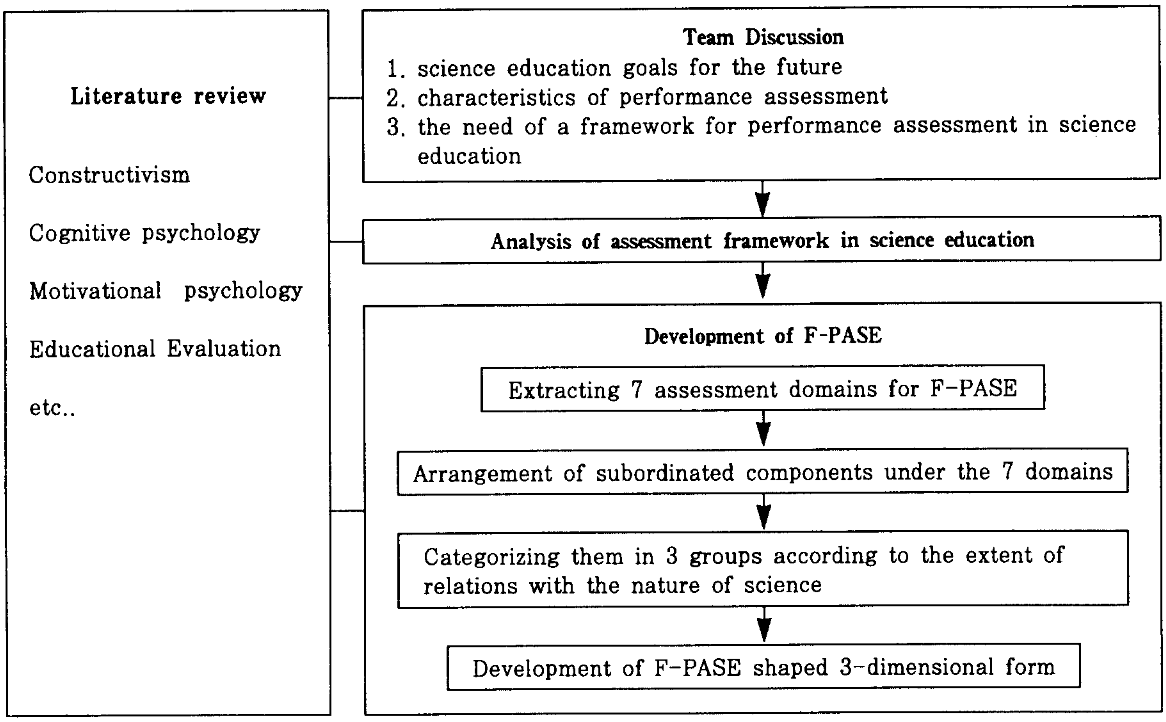


Fig. 1. Research procedure

# Ⅳ. Result

## 1. Analysis of previous assessment framework

The perspective of previous assessment framework is based on absolutism, behavioral psychology. They have views of a learner as a passive being, a teacher as a giver of knowledge and a textbook as all of teaching, learning and evaluating. The assessment system pursues relative assessment, quantitative assessment, and result-centered assessment, indirect assessment, partial assessment at a time. The assessments' goals are selection, classification, arrangement of students, explanation, prediction, control of learning. The domains of assessment frameworks are considered science knowledge, especially declarative knowledge, science inquiry skill, science attitude. The framework of each domain is separated. The assessment frameworks have dimensions according to the domains, such as intellective domain, affective domain. The usable assessment methods are paper-pencil test by selective items, standardized test, large scale assessment.

### 1) 2-dimension assessment framework

We have agreed that they be called 2-dimension assessment frameworks, that the assessment frameworks have two domains as dimensions for assessing, and we have chosen and analyzed Bloom's, Klopfer's, and The Consultation for Science Education Improvement's framework.

As contents' dimensions and behaviors', scientific knowledge(declarative knowledge) and the level of behaviors are assigned, respectively.

### 2) 3-dimension assessment framework

We have agreed that they be called 3-dimension assessment frameworks, that the assessment frameworks have three domains as dimensions for assessing like APU's. We have chosen and analyzed APU's and Korean College Scholastics Ability Test's.

Their dimensions consist of scientific knowledge, science inquiry skill, scientific context. When making items for assessing or evaluating, they must be considered.

### 3) Science Performance Assessments' Frameworks in nation or abroad.

Foreign-designed science performance assessments characterastically have a teaching-learning module form, because they have a particullar framework which is apt to be adopted to only its own performance assessment instrument, it cannot be a general framework (BSS, 1995; CSBE, 1990; IEA, 1997; KDE, 1991; NSRC, 1995).

Most Korean performance assessment instruments, moreover, don't have frameworks for performance assessment (KFTA, 1998; IHES, 1997; IJES, 1997; KSES, 1997).

## 2. Comparison of previous framework between F-PASE

F-PASE is based on constructivism, post-modernism as relativism, and cognitive psychology. It has views of a learner as an active being, a teacher as a guide and facilitator of learning, and a textbook as an assistant material of teaching, learning and assessing. The assessment system pursues absolute, qualitative assessment, process and result-centered assessment, direct assessment, total and continuous assessment, and small scale assessment. The assessments' goals are guidance, advice, improvement, understanding, reconstruction of students' learning. The domains of F-PASE are considered to be science inquiry thinking, science inquiry skill, science attitude, application of scientific knowledge, communication, creative thinking, reflective thinking. F-PASE is centered on ability whereas the previous is on knowledge. F-PASE is characterized as a holistic framework with whole domains selected in it. The usable assessment methods are quite varied.

The result of the comparisons is presented on [Table 1].

## 3. The Framework for Performance Assessment in Science Education (F -PASE)

Seven domains and their subordinate components are selected for F-PASE. They are constructed in the configuration of a cone [Fig 2]. Seven domains are grouped in three categories according to the extent of relations with the nature of science. These seven are grouped into three categories, science specific abilities and perspectives, general abilities, and intermediated abilities. As in [Fig.2], the three categorized groups are placed vertically. General abilities are placed at the bottom, scientific abilities at the top and intermediate abilities in the middle. The domains and their subordinate components are placed like ribs of a fan[Fig.2].

In [Fig 2], the solid line represents the ideal maximal point (infinite quality), and the dotted line

**Table. 1.** Comparison of previous framework between F-PASE

| comparison criteria \ assessment framework | PREVIOUS FRAMEWORK (Bloom's, Klopfer's, APU's) | F-PASE |
|---|---|---|
| CONCEPT OF ASSESSMENT FRAMEWORK | taxonomy of assessment objectives, framework categorized as several domains of assessment objectives, It has functions that teachers or developers could certify as assessment objectives to maintain balance between domains. | |
| PERIOD OF APPEARANCE & USAGE | the early and middle periods of 20th century | from the last of 20th century to the present |
| CONDITION OF AGE | industrial age, production system for large amount of a few kind of goods | informational age, production system for small amount of many kinds of goods |
| PERSPECTIVE OF TRUTH | absolutism | relativism |
| PHILOSOPHICAL BACKGROUND | positivism, rationalism, empiricism | constructivism, phenomenalism, analytics, post-modernism |
| VIEW OF KNOWLEDGE | objective fact and principles, independent of individual, emphasis on accumulation of objects and knowledge | creation, construction, reconstruction by individual, emphasis on construction and elaboration of relations between concepts |
| LEARNING VIEW | behavioral psychology<br>linear · hierarchical · continuous process<br>emphasis of general and objective condition, importance for learners to memorize and re-produce knowledge | cognitive psychology<br>continuous change of cognitive structure<br>emphasis of concrete and subjective context, importance for learners to understand and reconstruct concepts |
| VIEW OF LEARNER | passive being<br>re-producer of knowledge | active being<br>creator of knowledge |
| VIEW OF TEACHER | giver of knowledge | guider and facilitator of learning<br>learning colleague |
| ROLE OF TEXTBOOK | All of teaching, learning and evaluating | assistant material for teaching, learning and assessing |
| VIEW OF ASSESSMENT | view of assessment for selecting, emphasis of relative, quantitative assessment<br>result-centered assessment | view of assessment for developing, emphasis of absolute, qualitative assessment<br>process and result-centered assessment |
| VIEW OF TEST | view of measurement | view of evaluation, view of holistics |
| GOAL OF ASSESSMENT | selection · classification · arrangement<br>explanation · prediction · control | guidance · advice · improvement<br>understanding · reconstruction |
| DOMAINS CONSIDERED IN ASSESMENT FRAMEWORK | scientific knowledge, science inquiry skill<br>science attitude<br>:importance to declarative knowledge | science inquiry thinking, science inquiry skill, science attitude, application of scientific knowledge, communication, creative thinking, reflective thinking<br>:importance to ability |
| DIMENSION AND FORM OF FRAMEWORK | 2 dimension: X, Y axes<br>3 dimension: X, Y, Z axes | 3 dimension: cone-shaped, solid configuration in 3 dimensional space |
| CHARACTERISTICS OF FRAMEWORK | separated framework according to domain | holistic framework inclusive of every domain |
| USABLE ASSESSMENT METHODS | paper-pencil test by selective items, indirect assessment, partial assessment at a time, standardized test, large scale assessment | various methods, direct assessment, total and continuous assessment, small scale assessment |

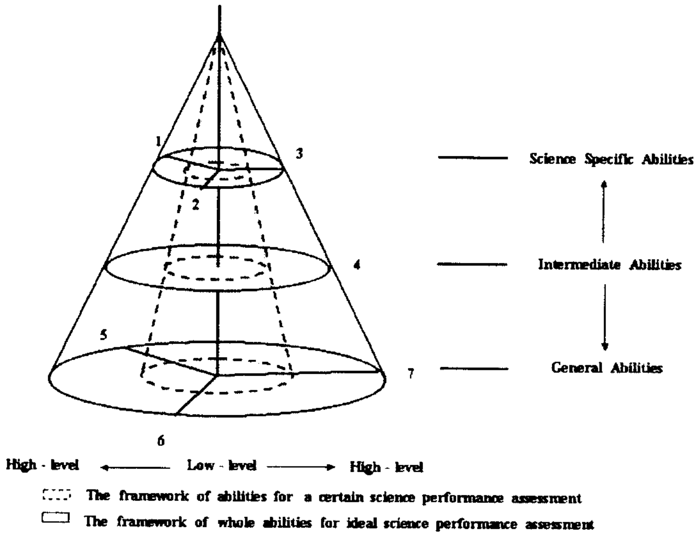


Fig. 2. The configuration of F-PASE

represents a certain science performance that is to be asessed. In other words, the large transparent cone is the highest (the ideally largest) framework that represents all abilities that a science performance assessment could have, and the small inner cone is the framework that a certain science performance assessment may have. The seven categorized domains are as follows;

### 1) The Domains of Scientific Abilities and Perspectives

(1) Scientific Attitude: The value, attitude and emotion related to science

- Curiosity (Interests) · Rationality · Pause of judgment · Modesty · Openness
- Criticism · Objectivity · Honesty · Awareness of scientific knowledge's limitation

(2) Scientific Inquiry Thinking

- The abilities of beginning inquiry: Awareness of problems, Hypothesis formulating
- The abilities of designing inquiry: Controlling variables, Designing Experiment
- The abilities of performing inquiry: Observing, Classifying, Recording data, Inferring, Predicting
- The abilities of manipulating data: Interpretation, Transformation, Analysis
- The abilities of generalization and evaluation

(3) Scientific inquiry skill: manual skills

- Measurement
- Manipulating experimental instruments
- Using a computer

### 2) The domain of intermediate abilities

(1) Application of relevant scientific knowledge

- Selecting relevant knowledge to solve a problem

· Applying adequate concepts to solve a problem

### 3) The domains of general abilities

(1) Communication

· Informing others of one's own thought. Understanding of the others' thoughts.

· Intervention of opinion: The ability of intervening in a dispute and carrying out an agreement.

· Visualization: The ability of presenting one's thought with visual aids to communicate with others

· Using information technology: The ability of finding and using information and informing others of one's own ideas using various types of electronic materials such as internet sites, and CD ROM as well as related literature to communicate with others

(2) Creative thinking

· Sensitivity to problems

· Originality: Generating unusual ideas(Guilford, 1988)

· Flexibility: Generating different types of ideas or ideas from different perspectives(Guilford, 1988)

· Elaboration: Adding to ideas to improve them(Guilford, 1988)

· Fluency: Generating many ideas(Guilford, 1988)

· Reorganization

(3) Reflective thinking

· The ability of self-reflection

· The ability of self-evaluation

· The ability of constructing and producing new scientific knowledge through reflective thinking process

## 4. The Structure of F-PASE

### 1) Direction of F-PASE

(1) Up and Down

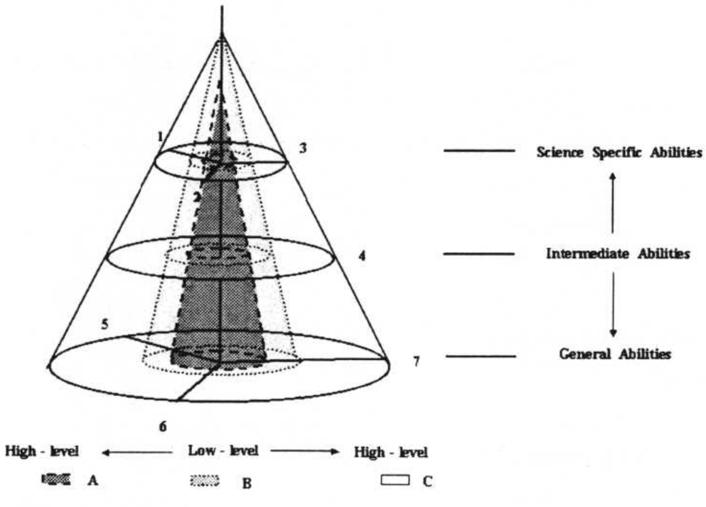


Fig. 3. The configuration in the direction

The direction of up and down is related to the extent of relevance in the nature of science(science speciality). However, it dose not mean that the general abilities on the bottom are not scientific. Definitely, all abilities in this framework are scientific. That is, they are very useful abilities for scientific problem solving. Moreover, abilities of a general domain have broader chances of applications, such as social domain, verbal domain, and art field, than scientific domains. The[Fig. 3] illustrates the configuration showing the direction of up and down. In [Fig. 3], A represents the framework of a certain science performance assessment whose science speciality are less emphasized than B, which is the framework for another science performance assessment. Hence, while A may be a framework for lower-grade students, B may be the one for higher-grade students. C means the ideal maximal point (infinite quality) of abilities that science performance assessment persues. One figure of framework means one assessment tool(or instrument)' s framework, so that A and B are adopted to two different tools each. The tool for low-grade students in elementary school may have a framework like A, and it may be represented by several shaped according to the differences of abilities of individual students in several domain. This is related, however, to practical implementation, so that it shall not be mentioned here.

(2) From the center to edge

The direction from the center to edge is related to the level of ability in each domain and its components. The closer to the center axis, the lower level of students' ability. On the contrary, the outer from the center, the higher level of students' ability. In [Fig. 3] A represents a case intended to assess lower level abilities than B.

### 2) Volume

In [Fig. 3], the volume of the solid figure means the height of science speciality and levels of assessed abilities in a science performance assessment. [Fig. 3] could show what the difference of the volume means.

### 3) Shape and Balance

Not all science performance assessments' frameworks could be a cone-shape. Rather, it is more felicitous that the cone shape is such an ideal form that a few might have a cone shaped framework. The actual framework shape is represented so variously, according to what a science performance assessment is intended to assess.

[Fig. 4] illustrates the shape of an example which has unbalanced assessment domains. In this figure, the domain 5 does not exist, and the domains 6 and 7 are lower than the others.

If a science performance assessment tool assesses ability levels in all domains of F-PASE, it will have a cone-shaped assessment framework. If another science performance aseeessment tool assesses ability level with balance among all domains, in other words, it represents the a fitted level of students' abilities in all domains of F-PASE, it will have a right-circular-cone-shaped assessment framework with balance. [Fig. 5] is an example that represented the assessing level of domain 3 at higher than domain 1 and 2.

## 5. The Strength of Framework for Performance Assessment in Science Education(F-PASE)

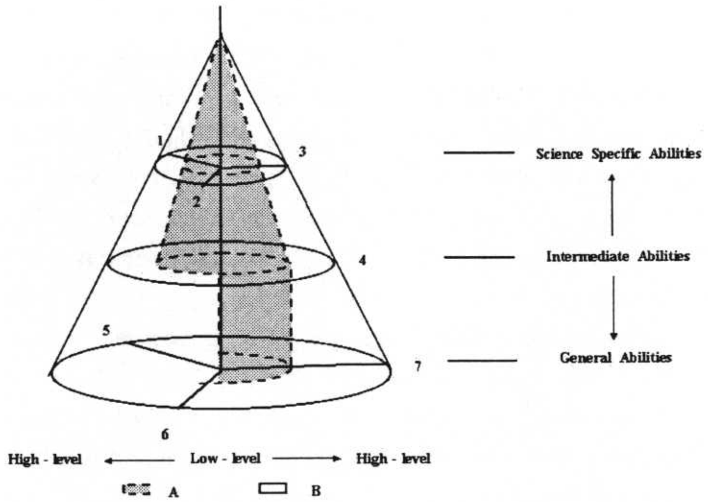


**Fig. 4**. An example of various shaped framework

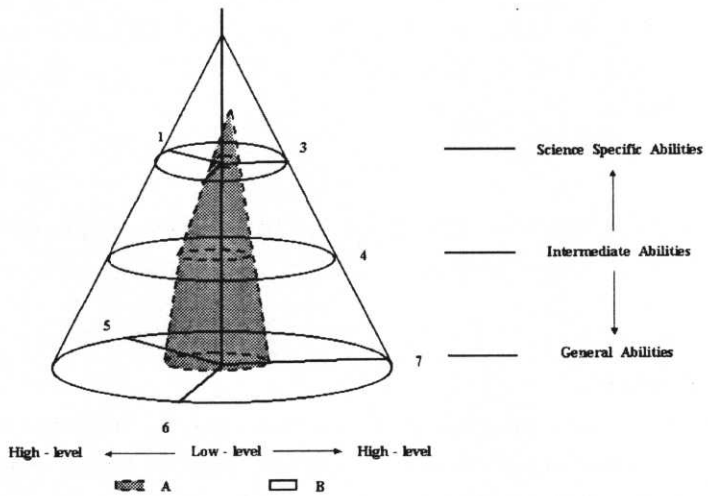


**Fig. 5**. a F-PASE of unbalanced level of ability of each domain

First, F-PASE is focused on students' competencies (abilities) for a task, while previous frameworks are focused on scientific knowledge in items. Second, in F-PASE, multi-domains are considered as a whole (Chittenden, 1991; Lazzaro & Park, 1994; Meisels, 1993; Perrone, 1990; WCEA, 1993; Herman, *et al.*, 1992) and they are built into a solid body as a cone. In previous frameworks, there are two dimensions of contents and behaviors; the behavoir might be one of domains, such as cognitive domain, affective domain and psychomotor domain and the contents are scientific knowledge. Such assessment administrated by the frameworks has a limitation to understand students' learning and abilities. Third, F-PASE has included students' various abilities assessed by performance assessment. The abilities will help students prepare for the 21st century because it is developed with consideration of human beings for the future. Fourth, F-PASE shows the relative position of a certain science performance assessment in the ideal framework, which is represented by a large cone with solid line[Fig. 2~ Fig.5].

## V. Conclusions and Implications

We have developed a framework for science performance assessment, which may be useful for science teachers to understand and assess their students' scientific abilities. We have extracted seven domains covering students various abilities as the important objectives of science performance assessment and grouped them into three categories: General, Science specific, and Intermediated abilities. And we developed an F-PASE with three dimensional solid figured structure, and illustrated it as the configuration of a cone. The F-PASE is useful for science teachers to develop and select a science performance assessment as well as to have a more advanced understanding of their students' abilities.

This framework would give us a new vision about a framework in learning and teaching science. In addition, it will be a useful tool for science teachers to understand and assess their students' variable abilities. As a creative and novel product, F-PASE will help various important abilities be assessed in science performance assessment.

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