〈논 문〉

An Investigation of Fifth and Eighth Grade Korean Students' Misconceptions of Photosynthesis

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1. Introduction

Concept learning has been the subject of research for many years. Since the beginning of the 1980's, research on people's misconceptions of scientific concepts has been active with mech interest in cognitive aspects of learning (Helm and Novak, 1983;and Novak, 1987).

Many studies showed that people hold some incorrect or partial conceptions of natural phenomena occurring around them; those conceptions were hard to change by the so-called traditional instruction (Smith and Anderson, 1984;Clough and Driver, 1986;and Pines and West, 1986).

In the biological science, studies on students' misconceptions have been performed in the following areas:phtosynthesis (Simpson and Arnold, 1982;Roth, 1985;Halsam and Treagust, 1987);ecosystem (Marek, 1986);Mendel's laws :Kinnear, 1983);animal identification and classification (Trowbridge and Mintzes, 1985);natural selection (Brumby, 1984);and osmosis (Friedler, Amir and Tamir, 1985).

One of the importance of misconception study in education is on the relationship of students' new learning to their existing knowledge. It was argued that what the learner already knows is the most important single factor influencing learning(Ausubel, Novak, and Hanesian, 1978). What people do, or do not learn from classroom instruction is determined, to some degree, by what they bring to the classroom. What kind of knowledge people can represent is also determined by logical reasoning ability, application of knowledge and experiences relevant to scientific concepts, such as instruction and extracurricular activities.

Some studies showed that there were relationships between students conceptions of scientific concepts and logical reasoning ability.

Especially people's Piagetian formal operations were found to be required for complete or correct understanding of some physical concepts (Champagne, Klopfer and Anderson, 1978;Wheeler and Kass, 1978;Shayer and Wylam, 1981;and Gabel, Samuel, and Hunn, 1987), Driver(1981) suggested that the logical order of concepts is not necessarily the same as the psychological order. Several Piagetian studies revealed that familiarty with concepts through experiences or instruction was related to increase in use of formal operations(Lawson, 1982;and Renner and Cote, 1985).

2. Purposes and Problems

It was the purpose of this study to obtain information on students' conceptions of selected biological phenomena related to photosynthesis and then to investigate the relationships between students' understandings of the concepts and textbook emphasis, Piagetian logical reasoning ability and student background variables.

The following questions were explored in this study :

1. What are the students' understandings of concepts related to photosynthesis ?
2. What is the relationship between students' understanding of concepts and the textbook emphasis of the concepts ?
3. What is the relationship between students' understandings of concepts and Piagetian logical reasoning ability ?
4. What are the relationships between students' understandings of concepts and student background variables such as sex, parents' educational level, science grades, attitudes toward science classes, extracurricular activities, science learning, science as favorite subject and science learing style ?
5. How are the variables which account for most of students' understandings of concepts different between fifth and eighth grade levels ?

3. Research Design and Procedures

1. Overall Design

Three instrements were developed for this study. The Photosynthesis Concepts Test (PCT) was developed as one means of obtaining information about students' understanding of concepts related to photosynthesis. The Piagetian Logical Reasoning Test(PLRT) was developed for the purpose of assessing students' achievement of three reasoning skills-control of variables, combinatorial reasoning and correlational reasoning. These reasoning skills were judged to be prerequiste to solve most items of the PCT. A questionnaire was developed to gather student background information and included educational level of parents;along with student data regarding science grades, attitudes toward science classes, extracurricular activities, science learning, science as favorite subject, and science learning style.

Biology textbooks used by classes from fourth through eighth grades were analyzed in terms of their emphasis on the contents assessed by the PCT instrument.

After administration of the above instruments, relationships of the achievement of the PCT with textbook emphasis, logical reasoning ability, and student data were investigated.

2. Population

The population of the study consisted of 201 fifth-grade Korean students in four classes from two elementary schools and 239 eighth-grade Korean students in four classes from two junior high schools. All the schools were located in the innercity of Seoul, Republic of Korea. The communities to which these schools belonged were very developed and within the realm of the economical and cultural centre.

3. Development of the PCT and PLRT Instruments

1) Photosynthesis Concepts Test (PCT)

Procedures involved in the development of the PCT included (1) selection of concept areas; (2) construction of a concept map using these concepts; (3) construction of a hierarchy of the concepts (Figure 1);and (4) construction of items, reflecting patterns of items that progressed from concrete to abstract, simple to complex, familiar to less familiar, and factual-based

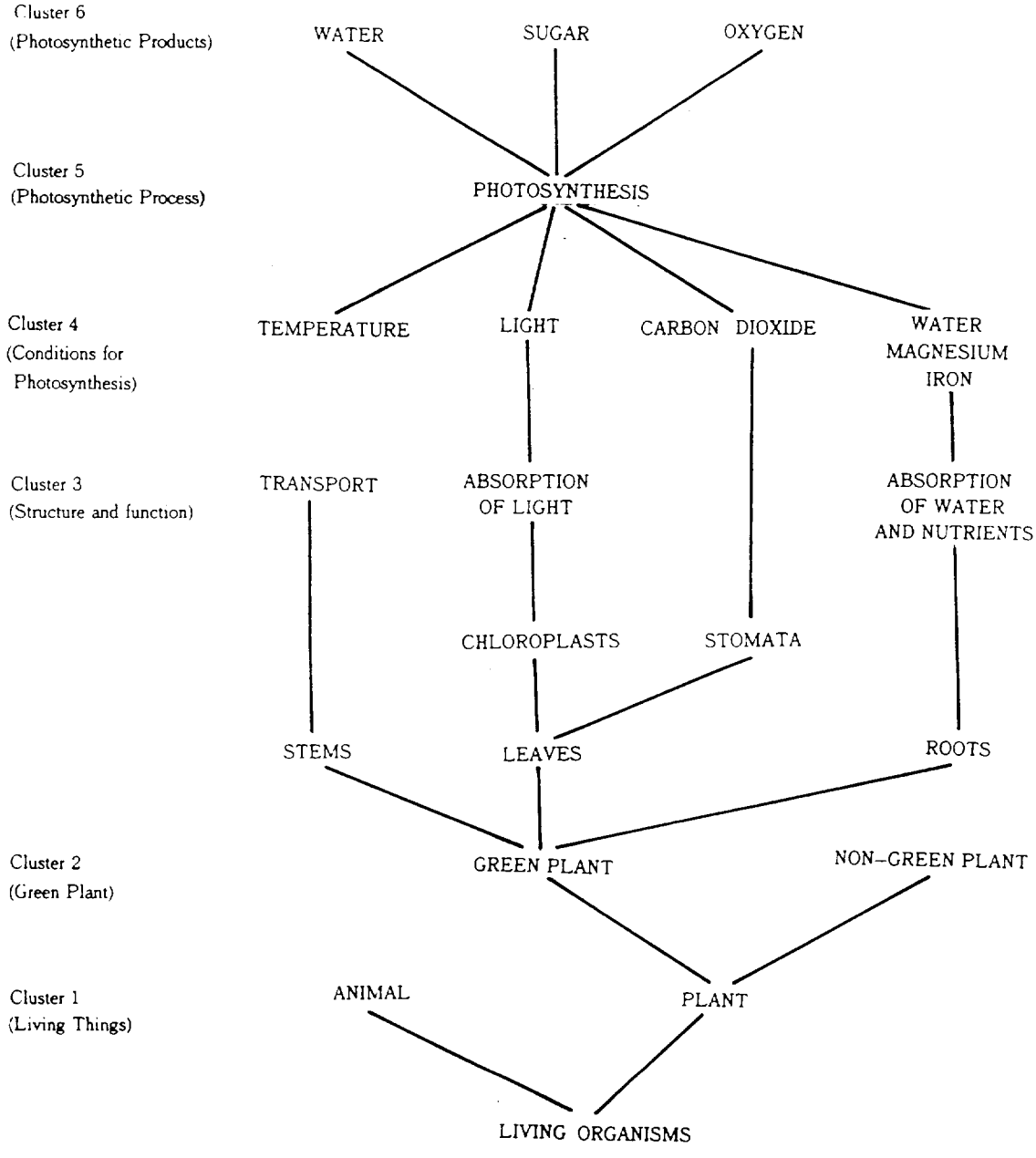

Figure 1: CONCEPT HIERARCHY AND SUBORDINATE CONCEPTS

to higher order questions. These items were revised based upon test and interview with pilot groups.

The PCT was intended to measure six groups of concepts related to photosynthesis The divisions focused on : (1) plant and animal identification; (2) characteristics of green plants; (3) plant structure and its corresponding functions; (4) conditions for photosynthetic processes; (5) photosynthetic processes;and (6) photosynthetic products.

2) Piagetian Logical Reasoning Test (PLRT)

The PLRT was developed to assess students'reasoning skills-control of variables, combinatorial reasoning, and correlational reasoning-which were involved in the PCT. As to each of the three reasoning skills, three Piagetian developmental levels-concrete, transitional and formal-were appied.

Based upon the argument that each developmental level has its own unique applications in terms of "reasoning patterns" (Karplus, 1979), the genereal and specific applications of three reasoning skills were established at each developmental level.

A total of 12 items were constructed based upon these general and reasoning-specific applications.

4. Validity and Reliability of the PCT

1) Validity

The high degree of coverage of the test item by the textbooks was revealed through the comparison of the items with science textbooks of forth through eighth grades and confirmed by a panel consisting of two science educators and a botanist.

The items of the PCT was develped to include concrete to formal reasoning requirements. The assignment of the items by reasoning level was judged valid by the panel.(See the dissertation for the required reasoning level and skill(s) of each item.

It is important that instruments used in misconception study measure both concept understandig and logical reasoning dimensions for accurate interpretation of student achievement. Both the pilot study and this study results showed that : (1) the scores on the PCT tended to agree with the scores as predicted by the students' logical reasoning ability; (2)formal thinkers did better on the PCT items requiring transitional and formal level reasoning than concrete thinkersdid.

2) Reliability

The internal consistency of the PCT was calculated by the reliability procedure of SPSSx(2nd ed., 1986) which computed coefficient alphas. The coefficient alphas of the PCT were 0.75 for the eighth-grade students;and 0.58 for the fifth-grade students. These values suggested that this test was relatively appropriate for the eighth-grade students, but difficult for the fifth-grade students. These reliability coefficients were acceptable since this test was designed to measure the mastery of several concept clusters of which items required differdnt level of knowledge.

The repeated use of the PCT with the two grade groups showed that higher grade students scored higher according to the logical direction of easy to difficult items.

Comparison of the pilot study group with Korean sample presented a similar distrbution of the scores. The test appeared to yield similar results with different group of stedunts.

5. Validity and Reliability of the PLRT

1) Validity

A panel were given the PLRT and the table of general and specific applications of reasoning patterns. All of the members judged the instrument to be appropriate for assessing the applications. The study data revealed that the group means of the items were categorized into three groups-concrete, transitional, and formal level. Eighth-grade students scored higher on the transitional and formal level items of the PLRT than fifth-grade studentsdid.

2) Reliability

The reliability of the PLRT was calculated by the reliability procedure of the SPSSx. The reliabilities of the PLRT were. 70 for the fifth-grade students, and 64 for the eighth-grade students. These reliability coefficients were acceptable, with it considered that the test consisted of only 12 items and the test items

were constructed to assess different types and levels of reasoning patterns.

6. Textbook Analysis

The biology sections of the science textbooks were analyzed in terms of the degree of coverage of contents related to the PCT items. The textbook emphasis was tated by class hours which were assumed to spend to cover the contents related to the test items. Only the total scores for fourth and fifth grades and for fourth through eighth grades were used in this analysis.

7. Analysis of Data

1) Statistical Analysis

The Frequency procedure and Pearoson Correlation Procedure of SPSSx were employed for descriptive analysis of the data.

After scrutinizing the correlations with some significant level among the variables, selected variables were subject to regression analysis to find the variance of the PCT score accounted for by these variables. Since textbooks emphasis varies along the PCT items, not students, it could not be subject to multiple regression analysis, but consistency of textbooks emphasis with PCT achievement was assessed by one-sample Chi-square test.

2) Misconception Analysis

Students misconceptions were identified by comparing two grade students' responses to the PCT items. The persistency of and improvement in incorrect conceptions were explained in relation to other variables, such as Piagetian logical reasoning ability, their previous learning in science textbook emphasis, etc.

4. Results

1. Summary of Descriptive Analysis Results

(1) The educational level of fathers of the participating students was very high. Eighty one percent of fathers of fifth grade, and 32 percent of fathers of eighth grade completed a college level education.

(2) Mothers of the participating students were well educated, even though not as high as the fathers. Sixty one percent for fifth grade and 12 percent for eighth grade completed a college level education.

(3) Seventy seven and 87 percent of fifth-grade students reproted receiving high grade in science in the year(1987) and in the previous years, respectively.

(4) Over 50 percent of eighth-grade students reported receiving higher science grades(A or B)in the year and in the previous years;about 15 percent of the students reported lower grades(D ro F)in the year and in the previous years.

(5) Grading patterns for other subjects appeared to be similar to science grades for both groups.

(6) Sixty-eight percent of fifth-grade students felt that they learned a lot of science in the year;only five percent felt they learned very little

(7) Forty percent of eighth-grade students felt that they learned a lot of science in the year;16 percent felt they learned very little.

(8) Thirty-five and 42 percent of fifth-grade students reported that they always liked science classes in the year and in the previous years, respectively;17 and three percent of the students reported never or rarely liking science classes in the year and in the previous years, respectively.

(9) Twenty-nine and 16 percent of eigfth-grade students reported that they always liked science classes in the year and in the previous years, respectively;13 and 22 percent of the students reported never or rarely liking science classes in the year and in the previous years, respectively.

(10) Eighty-four percent of fifth-grade students and 50 percent of eighth-grade students indicated that science was their favorite or second favorite subject.

(11) Seventy percent of fifth-grade male and 40 percent of fifth-grade female students planned to take additional science courses in the future;57 percent of eighth-grade males and 32 percent of eighth-grade female students did.

(12) Most frequent science-related activities for

fifth-grade students were:1)read science articles in magazines or books (78 percent);2)watch science T.V. programs (65 percent);and 3)read science articles in newspapers(53 percent).

(13) Most frequent science-related activities for eighth-grade students were:1)watch science T.V. programs (70 percent);and 2)read science articles in magazines or books(59 percent)

(14) The most favorite learning styles for fifth-and eigfth-grade students were in common:first doing laboratory activities;second, listening to lectures. Ten percent or less of the students selected each of working in outdoor activities 'working in a group' and 'reading by myself' as their favorite learning style.

(15) Forty-five percent of fifth-grade students and 75 percent of eighth-grade students were at the transitional level. The percentage of students at each reasoning level was indicated in Table 1.

Table 2 Correlation Matrix for Grade 5 and 8 Students

	SEX	F	M	SCT	SCL	FUNL	FUNT	EPIS	PTL	BTL
SEX		.00a	.02	-.04	-.01	.04	-.10	-.11	-.04	.07
		.10b	.09	.21*	.18*	-.00	.27*	.16*	.15	.27*
F			.59*	.32*	.18*	.10	.01	.02	.24*	.02
			.61*	.36*	.32*	.03	.08	.23*	.32*	.34*
M				.26*	.23*	.13	.03	.04	.21*	.10
				.24*	.23*	.00	.14	.20*	.19*	.15
SCT					.63*	.19*	.24*	.31*	.38*	.21*
					.74*	.08	.27*	.40*	.35*	.54*
SCL						.23*	.11	.24*	.32*	.28*
						.21*	.18*	.32*	.36*	.49*
FUNL							.22*	.20*	.19*	.14
							.10	.25*	.21*	.12
FUNT								.56*	.10	.10
								.30*	.22*	.15
EPIS									.19*	.23*
									.31*	.28*
PTL										.44*
										.48*

* Significant at p.<.01

a: First row of each variable indicates correlation coefficients for fifth-grade students.

b: Second row of each variable indicates correlation coefficients for eighth-grade students.

SEX sex of students(male 1, female 0),

F educational level of father

M educational level of mother

SCT science grade which they got in the year

SCL average science grade in previous years

FUNL attitude toward science class in previous years

FUNT attitude toward science class in the year

EPIS extent to which students thought they learned science in the year

PTL total score of the PLRT

BTL total score of the PCT

Teble 1 Percentage of Fifth-and Eighth-Grade Students at Each Reasoning Level

Reasoning Level*	Fifth Grade (n=201)		Eighth Grade (N=239)	
	n	%	n	%
Preconcrete	8	4.0	3	1.2
Concrete	102	50.7	57	23.8
Transitional	78	38.8	147	61.8
Formal	13	6.5	31	13.0

* Three reasoning levels were determined based upon the principle that in order to say a student has reached a certain reasoning level, he responded correctly on at least two-thirds of the items measuring the reasoning level and all the items below that level. As the result, the preconcrete reasoning level corresponded to total scores 0 to 3; concrete 4 to 7, transitional 8 to 10; and formal 11 to 12.

Table 2 presents the correlation results for both grade students regarding the variables indicated in the above descriptive results and the PCT scores.

2. Students' Misconceptions of Photosynthesis:Analysis from the PCT Instrument Data

1) Misconceptions Identified in the Study

The results of the study showed that most students had misconceptions of phenomena related to photosynthesis. The meaning of "making food," the difinition of food the way plants get food, the functions of light in relation to photosynthesis, the functions of roots and leaves, and the relevancy of magnesium and iron to photosynthesis were areas in which more than half of both group students gave incorrect responses. Most of these misconceptions seemed to be caused by misperceiving observable phenomena around students. Misconceptions shown by most students(at least more than 50 percent)and achievement presented by percentage of students who gave correct responses in the relevant item, were presented in Table 3.

2) Improvement of Students' Concept Understanding at the Upper Level

Most of the items on which eihth-grade students showed much improvement compared with fifth-grade students belonged to three concept clusters, Four, Five, and Six which indicated conditions for photosynthesis, photosynthetic processes and photosynthetic products, respectively(see Figvre 1 for the concept clusters).

These items were regarding specific concepts of photosynthetic processes in a system and interaction of organisms in the system(#9, 10, 11, 12), specific products of photosynthesis(#8, #16, and #20)and

Table 3 Misconceptions and Achievement Related to the BCT items

Content	Conceptions	Achievement Level
"Making Food"		
	5th Grade:Half of students could not match "making food" to the unique function of plant.	44%
	8th Grade:the same as in the 5th grade. Some students misinterpreted the phrase "making food" into the process that animals search for and catch their preys.	50%
Definition of Food		
	Both Grades:Most of both grade students showed that food is something edible so that people or organism cannot eat or drink. Plants obtain food "by absorbing minerals and nutrients via roots," "by absorbing waters," as well as "by making food for themselves	0%
Functions of Light		
	5th Grade:Light was a source of energy for plants, but not absolutely needed by plants. "Plants can survive without light, but look sick, unhealthy, or turn yellow.	30%
	8th Grade:Some students answered, "Plants grow toward the source of light, but without light, plants grow straight.	60%
Functions of Roots		
	5th Grade: Related the functions of roots with light, air or warmth.	52%
	8th Grade:The same as in the 5th grade.	56%
Functions of Leaves		
	5th Grade:Related the function of plant leaves to "catching dew or rain," "capturing warmth of the sun," and "shading the tender younger shoots from the hot sun."	0%
	8th Grade:The same as in the 5th grade.	9%
Requirement of elements for photosynthesis		
	5th Grade:Most of the students responded in the way that magnesium and iron are not required for photosynthesis.	24%
	8th Grade: The same as in the 5th grade.	21%

knowledge of protein, glucose, and fat(#21e, #21f, #21g, #21i).

These items had common characteristics in that they obtained high textbook emphasis at upper grade levels, and they required higher reasoning levels.

3) Major Things Related to Improvement between Lower and Upper Levels

The variables which were salient in correlation analysis were selected and subjected to multiple regression analysis.

For eigth-grade students, the PLRT achievement (coded as PTL) accounted for 19 percent of the variance of the PCT achievement (coded as BTL). Previous science grade(coded as SCL) accoented for additional three percent of the variance.

For eighth-grade student, science grade in the year-(coded as SCT) accounted for about 30 percent of the variance of PCT achievument. The PLRT achievement (PTL) accounted for the additional 9 percent of the variance. Sex added two percent to the variance (see Table 4 for the regression analysis results).

The results of regression analysis for both grade levels showed that previous learning and Piagetian reasoning ability soolted for the most protion of the explicable variance of the PCT achievement. However, previous learning was the best predictor of the PCT achievement at the eighth grade, while Piagetian logical reasoning ability was the best predictor at the fifth grade. It suggests that students of low reasoning level were affected by reasoning skills required for understanding concepts more than by the previous learning;students of higher reasoning level were affected by previous learning more than the required reasoning skills.

4) Relationship between Textbook Emphasis and Item Achievement of the PCT

A significant correlation($r=0.67$, $p<0.001$) was obtained between textbook emphasis and item achievement by item.

The general tendency was that the students had high achievement on items on which science textbooks put high emphasis;low emphasis when there was low achievement.

5. Conclusion

The results of the study showed that students in both groups had misconceptions on concepts related to photosynthesis, that is, the meaning of "making food,"the definition of food, the use of light by plants, the functions of plant roots and leaves, photosynthetic products and requirements of elements for photosynthesis.

The persistency of misconceptions of the way plants get food was found by several studies(Roth, 1985;Smith and Anderson, 1984;and Wandersee,

Table 4 Stepwise Multiple Regression Analysis Results Indicating Which Predictor Variables Contributed Statistically Significant($p<.05$) Increments of Variance to PCT Scores at Both Grade Levels

Criterion Variable(BCT score)					
5th grade			8th grade		
Variables entering	R	R SQ. (percent)	Variables entering	R	R SQ. (percent)
PTL	.422	.191	SCT	.547	.298
SCL	.468	.210	PTL	.628	.389
			SEX	.644	.406

PTL total score of the PLRT
SCL average science grade in previous years
SCT science grade in the year
SEX sex of students

1986). Roth's study revealed fifth-grade students' misconceptions of the definition of food;this study showed that the same misconceptions as she found from fifth-grade students were still held by eighth-grade students.

Research findings by Murr(1986), Halsam and Treagust(1987), and Bell(1985) revealed misconceptions which older students held in higher level concepts of photosynthesis. The results of this study were consistent with their findings.

Improvement in students' understanding between fifth and eighth grades was shown in items regarding concepts which were emphasized by formal instruction and required higher reasoning levels.

In terms of both general improvement of student learning by instruction(Second International Mathematics Study, 1985;and Comber and Keeves, 1973) and reduction of misconceptions at upper grade levels(Halsam and Tragust, 1987;and Simpson and Arnold, 1982), the results of this study was consistent with the literature findings.

However, in some specific concepts such as the definition of food, misconceptions studies found little instructional imtact on reduction of misconceptions, as did this study (Adeniyi, 1985; Roth, 1985;and Friedler, Amir and Tamir, 1985).

The relevancy of Piagetian logical reasoning ability to reduction of misconceptions was also show in some, but not many studies(Wheeler and kass, 1978;and Champagne, Klopfer and Anderson, 1978). More studies on the improvement of misconceptions in relation to Piagetian logical reasoning ability need to be performed.

6. Recommendations for Futere Research and Pratice

1. Recommendations for Future Research

The following are recommended for future research based on this study :

(1) Replication studies involving the same levels of students, but with locations of suburban and rural areas, other than innercity;

(2) Studies on the effect of different high school biology textbooks on change of misconceptions;

(3) Experimental studies on change of students' identified misconceptions by modifications of instructional conditions in terms of the abstractness, appropriateness for conceptual change, and reasoning abiliy required;and

(4) Studies on the relationship between improvment of misconceptions and relevant Piagetian logical reasoning skills.

2. Recommendations for Practice

For school instruction to be designed to improve students' misunderstandings and increase their understandings,

(1) emphasize what you want to teach.

(2) assess students' previous learning related to what you want to teach, and make up for the deficiency or partial understanding based on special teaching plan.

(3) articulate science curriculum throughout grade levels in order that student's understandings on certain concepts can be connected to new knowledge within new context.

(4) analyze learning tasks in terms of reasoning levels and skills required;teach skills required if students are deficient of the skills;and general, teach the learning tasks at lower reasoning level, that is, at the concrete level in the case of tasks reqeiring transitional reasoning level, and at the concrete or transitional level in the case of the tasks requiring formal jreaisoning level.

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요 약

한국 국민학교 5학년과 중학교 2학년 학생들의 광합성의 대한 오개념 연구

조 정 일
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본 연구의 목적은 광합성과 관련하여 한국 국민학교 5학년과 중학교 2학년 학생들이 갖고 있는 오개념을 조사하고, 학생들의 개념이해 정도, 논리적 사고능력, 그리고 학생배경변수들 사이의 상호관계를 조사하는 것이다.

세가지의 도구들이 이 연구를 위해 개발되었다. 광합성 개념검사(Photosynthesis Concepts Test)는 광합성과 관련된 개념들의 이해를 평가하기 위해, 삐아제의 논리적 사고력 검사(Piagetian Cogical Reasoning Test)는 PCT에 포함된 3종류의 논리적 사고들, 변인 통제, 조합적 사고력, 상관관계 사고능력을 평가하기 위해, 그리고 실문서는 학생들의 배경변수들에 대한 정보를 얻기 위해 개발되었다.

이 도구들은 20명의 국민학교 5학년, 239명의 중학교 2학년 학생들에게 시행되었다.

이 연구의 결과는 두집단의 학생들이 "먹이를 만든다"는 의미, 먹이의 정의, 식물에 의한 빛의 사용, 식물 뿌리와 잎의 기능들, 광합성 산물, 그리고 광합성을 위한 조건들과 관련하여 오개념을 갖고 있음을 보여 주었다. 국민학교 5학년과 중학교 2학년 사이의 개념 이해의 향상은 식물에 의한 빛 이용의 본질, 한 체계내에서 생물들간의 물질 교환, 포도당, 지방, 단백질 등에 대한 지식에서 보여졌고, 그래프를 해석하는 능력에서 또한 중학교 2학년 학생들이 앞섰다. 향상을 보인 항목들은 교과서에서 보다 많은 강조점을 두거나 상위의 논리적 사고능력을 요구하는 것들이었다.

회귀분석 결과, 전년도 과학성적과 논리적 사고력이 PCT 성취도에 가장 예견력이 높은 두 변수이며 5학년의 경우 성취도의 약 22%의 변량을, 중2의 경우 성취도의 약 40%의 변량을 설명하였다.

후속연구로서 내용의 추상성, 적절성, 그리고 요구되는 논리적 능력면에서 교수조건의 변형을 통한 오개념의 변화와 감소에 대한 실험적 연구가 제시되었다.