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ABSTRACT

This document contains the following full and short papers on cognition and conceptual change from ICCE/ICCAI 2000 (International Conference on Computers in Education/International Conference on Computer-Assisted Instruction): (1) "A Method of Creating Counterexamples by Using Error-Based Simulation" (Tomoya Horiguchi and Tsukasa Hirashima); (2) "An Interactive Game System To Stimulate Word Associations" (Naoko Nitsu, Takeyuki Kojima, Bipin Indurkhya, and Yoshiyuki Kotani); (3) "Applied the Gray Relationship Matrix and Learning Obstacles Analysis on the Discovery Teaching" (Chao-Fu Hong, En-Yih Jean, Pei-Chin Wu, Chien-Miing Lia, and Tsai-Hsia Wu); (4) "Collaborative Learning vs. Cognition" (Madhumita Bhattacharya); (5) "Impacts of Unintellect Factors on the Design of CAI Courseware" (Xiaohua Yu and Qinzhu Zhang); (6) "Towards a Meta-Knowledge Agent: Creating the Context for Thoughtful Instructional Systems" (Elspeth McKay); (7) "Microgenetic Analysis of Conceptual Change in Learning Basic Mechanics" (Gary Chon-Wen Shyi and Shih-Tseng Tina Huang); (8) "Scientific Revolutions and Conceptual Change in Students: Results of a Microgenetic Process Study" (Benson M. H. Soong and Yam San Chee); (9) "The Effect of Virtual Reality Learning Transfer with Different Cognitive Style" (Jia-Rong Wen and Li-Ling Hsu); (10) "The Externalization Support System of Self-Explanation for Learning Problem-Solving Process" (Kazuhide Kanenishi, Takahiko Mendori, Masafumi Sawamatsu, and Yoneo Yano); and (11) "The Use of Animation as a Tool for Concept Learning" (Hung-Liang Lee). (MES)

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A Method of Creating Counterexamples by Using Error-Based Simulation

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The method of creating counterexample by using educational simulation is proposed. Error-Based Simulation (EBS) is used for this purpose, which simulates a learner's erroneous equation in mechanics problem. A learner's error is visualized as unnatural motion of a physical object. In order for EBS to be effective as counterexample, the followings are essential: (1) A learner can recognize the difference of unnatural motion in EBS from natural one in correct simulation, and (2) EBS must provide a learner sufficient information to understand the cause of error and to reach correct understanding. The former has been studied in the authers' previous works. In this paper, the latter is discussed. To identify a learner's error, misconceptions are classified based on problem-solving model, and are linked to their appearance on a learner's answer (error-identification rules). Then, to indicate the cause of error by EBS, unnatural motions in EBS are classified and linked to the misconceptions which they suggest (error-visualization rules). These functions are realized as rule-base systems. The architecture of EBS management system, which judges a learner's error and generates the suitable EBS using these functions, is proposed.

Keywords: **counterexample, simulation, mechanics, error, student model, motion perception**

1 Introduction

It is well known that cognitive conflict promotes learning process. It often occurs when a learner encounters the fact which is contradictory to her/his idea. Cognitive conflict motivates a learner to reconsider her/his idea, and often causes conceptual change [Gagne 85, Fujii 97].

Counterexample is useful for creating cognitive conflict. It provides a case in which a learner's idea doesn't account for the fact, or her/his procedure doesn't produce the correct solution.

However, one must be careful in using counterexample, because a learner often ignores or refuses it. Even when she/he accepts the counterexample, she/he needs some kinds of help to reach correct understanding. Without any assistance, a learner often comes to an impasse, or makes ad hoc rules which explain the exception only. Therefore, in using counterexample, the followings are essential [Fukuoka & Suzuki 94, Nakajima 97]:

(1) Counterexample must be recognized to be meaningful and acceptable. When the difference is clear and reliable between counterexample and a learner's expectation, she/he easily accepts it and reconsiders her/his idea.

(2) Appropriate assistance must be provided to lead a learner to correct understanding. Counterexample must include sufficient information for this. It will be helpful to explicitly describe the distinguishing attributes of counterexample.

Error-based Simulation (EBS) is an educational simulation which provides a learner counterexample. It simulates an erroneous equation made by a learner in solving mechanics problem. In EBS, a learner's error often appears as unnatural motion of a physical object, which differs from her/his prediction (She/he can usually predict the correct motion).

The authors have developed the method of generating effective EBS mainly from the above viewpoint (1) [Hirashima et al. 98, Horiguchi et al. 99]. The condition on which a learner can recognize the difference between EBS and correct simulation was formulated (Criteria for Error-Visualization: CEV), and the mechanism to estimate the quality of difference was proposed, which considers both clarity and reliability of the difference.

However, though such an EBS motivated a learner by indicating the existence of errors, it was not sufficient to lead her/him to correct understanding. It didn't provide sufficient information for this.

Therefore, this paper proposes the method of managing EBS from the above viewpoint (2). EBS must justly indicate the cause of a learner's error, and suggest how to correct it. The followings are the requirements and approaches for this purpose.

(a) The function which identifies the cause of error behind a learner's erroneous equation or her/his handwriting diagram.
Approach: First, construct a problem-solving model of mechanics. Secondly, based on the model, classify the misconceptions which occur in problem-solving as causes of errors. Thirdly, classify the appearances of the misconceptions on a learner's equation or handwriting diagram. Lastly, appearances and causes of errors are linked together correspondingly. These are called *Error-Identification Rules*.

(b) The function which generates the EBS indicating the identified cause of error by unnatural motion of a physical object.
Approach: First, classify the unnatural motions in EBS. Then, link them to the corresponding causes of errors, considering what kind of unnaturalness suggests what kind of misconception. These are called *Criteria for Cause-of-Error-Visualization*. With these criteria, EBSs are estimated their effectiveness. When there is no EBS which is judged effective, other teaching methods will be considered.

2 Previous works in Error-Based Simulation

Before proceeding to the main topic of this paper, we outline the stream of study in Error-based Simulation, which may be helpful to clarify the present problem and the position of this paper.

Stage 0 **[Hirashima et al. 98 for summary]**

The fundamental idea of EBS is very simple. In mechanics problem, many learners feel difficulty in thinking by equations, so EBS maps their equations from mathematical world to physical world. It embodies a learner's error as unnatural motion of a physical object, which makes it much easier to recognizc thc error. Here, we assume that unnatural motion in EBS is differ from a learner's prediction, that is:

Precondition-1: A learner can predict the correct motion (in spite of her/his erroneous equation).
This precondition is set through all stages of the research of EBS.

Stage 1 **[Hirashima et al. 98]**

Apparently, the key of this method is how a learner sees the difference between the unnatural motion in EBS and the predicted natural motion. At least, the difference must be noticed by a learner. When the difference of two motions is small, she/he may not notice it, or cannot judge which motion is correct (unfortunately, the ability of human vision is not so sensible). Therefore, we set the following assumption:

Assumption-1: EBS must satisfy CEV-1 and/or CEV-2 below to indicate the existence of error.

Condition for Error-Visualization 1 (CEV-1): There is a qualitative difference between the motion in EBS and the one in correct simulation, that is, the qualitative values of a physical object's velocity are different between them.

Condition for Error-Visualization 2 (CEV-2): There is a qualitative difference between the change of motion in EBS and the correct simulation, that is, the qualitative values of the derivative of a physical object's velocity are different between them.

Stage 2 **[Horiguchi et al. 99]**

When regarding EBS as counterexample, the viewpoints (1) and (2) in chapter 1 are important. We previously worked out how to estimate the effectiveness of EBS from the viewpoint (1). It is subdivided into two viewpoints: (1-1) how clear the error appears in EBS, and (1-2) how reliable the EBS is as counterexample.

From the viewpoint (1-1), the more CEVs the EBS satisfies, the more effective it is. In general, changing parameters of the mechanical system makes EBS satisfy more CEVs. For example, in Figure 2, the EBS based on erroneous equation $m2a = T + \mu m2g$ (Figure 2d) satisfies CEV-1. (The qualitative value of relative velocity between two blocks is [+], while it is [0] in normal case.) But, when the mass of m2 increases, the EBS becomes to satisfy CEV-2 besides CEV-1. (The velocity of m2 increases, while it decsreses in normal case.) We categorized the methods of parameter-change and their influence on the clarity of errors.

However, from the viewpoint (1-2), such parameter-change harms the reliability of EBS, because a learner feels it factitious to change parameters too largely. The smaller parameter-change the EBS has (no change is the best), the more reliable it is. This discussion is summarized as follows.

Assumption-2: From the viewpoint of clarity, EBS should satisfy more CEVs.

Assumption-3: From the viewpoint of reliability, EBS should have less parameter-changes.

Stage 3 **[just this paper]**

In estimating the effectiveness of EBS, there is another, and important viewpoint: whether the EBS provides appropriate information for correcting the error, that is, the viewpoint (2) in chapter 1. Stage 0-2 have been mainly concerned with how to make a learner notice the error, while at this stage, our concern is how to make him correct the error.

For example, consider the erroneous equation $m2a = T + \mu m2g$ (Figure 2d). From the viewpoint of reliability (1-2), the EBS shown in Figure 2c is generated. But it shows the string between two blocks shrinking, which may suggest something is wrong about tension of the string. It is misleading because the real cause of error is the friction of m2. In this case, the EBS in Figure 2e should be generated to indicate the cause of error. (It is generated when taking the viewpoint of reliability (1-2), but by accident.)

Of course, the viewpoints (1-1) and (1-2) are useful to impress on a learner the existence of error. However, in considering the error-correction, to generate EBS from the viewpoint (2) becomes necessary. It is the very topic of this paper.

3 Mechanism for Identifying the Cause of Errors

Now, we'll explain how to realize the functions described in chapter 1. The mechanism for identifying cause of errors is realized as follows:

1. to generate the correct solution by problem-solving mo del.
2. to specify the erroneous part of a learner's solution by comparing with the correct solution.
3. to identify the cause of error by applying the Error-Identification Rules, which link the appearance of erroneous part to its cause.

Here, a learner's solution means the equation and handwriting diagram made by her/him, from both of which the information about her/his problem-solving process is derived.

3.1 Problem-Solving Model

We deal with the mechanics problems of high school level, which ask a learner to set up equation of motion by using Newton's second law. The problem-solving process is divided into three steps [Robertson 90, Plötzner 94]:

step-1 to predict the motion of physical objects in the mechanical system qualitatively.
step-2 to enumerate the forces acting on each object.
step-3 to compose the enumerated forces and substitute them for the left side of formula $F = ma$.

Table 1. Force-Enumerating Rules (FERs) (abstract)

force	Rules for enumerating forces	
gravity	R0: r0-c1 Object-1 has mass m > 0	
	→	
	r0-a1 Gravity F to Object-1	Qualitative
	r0-a2 Direction. vertically downward	Qualitative
	r0-a3 Magnitude. F = mg	Quantitative
friction	R3: r3-c1 Object-1 and Object-2 are touching together ∧	
	r3-c2 coefficient of friction of touching surface μ > 0 ∧	
	r3-c3 normal force N acting on touching surface ∧	
	r3-c4 Object-1 and Object-2 are moving oppositely along the tangent	
	→	
	r3-a1 friction Ff1 to Object-1	Qualitative
	r3-a2 friction Ff2 to Object-2	Qualitative
	r3-a3 Direction(Ff1). opposite to the velocity of Object-1	Qualitative
	r3-a4 Direction(Ff2). opposite to the velocity of Object-2	Qualitative
	r3-a5 Magnitude. Ff1 = Ff2 = μN	Quantitative

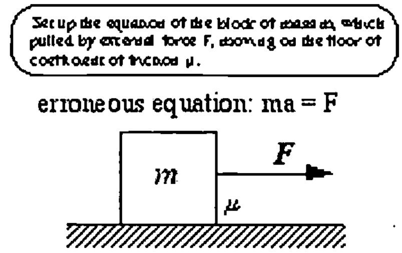


Figure 1. Example Problem-1

In step-1, a learner predicts the motion of objects in the system, and gives each object acceleration vector. Approproate axes are also set up. In step-2, she/he enumerates the forces which aren't given in problem description. Both qualitative knowledge (what kind of force acts in which direction?) and quantitative one (algebraic description of the magnitude of force) are used. In step-3, she/he decomposes/composes the enumerated forces along the axes, and substitute them for the formula $F = ma$.

In this paper, we don't model the error-occurring process in step-1, because it is presupposed that a learner correctly predicts the qualitative motion of objects in using EBS (Precondition-1 in chpter 2). We also omit the occurrence of error in step-3, which mostly concerns the knowledge of vector calculation.

Therefore, modeling step-2 is our central issue. Takeuchi and Otsuki (1997) considered that a learner constructs a model of causal structure of mechanical system, with which she/he infers the occurrence and propagation of forces. They formulated this process as a set of production rules. We modify them considering their qualitative/quantitative characteristics. A part of our model is shown in Table 1. The rules are called Force-Enumerating Rules (FERs).

3.2 Error-Identification Rules

In our model, a learner's errors are considered as the ones of FERs. The errors of FERs themselves and the ones in their application are included. In fact, these errors appear as the missing/extra/errors of the term of force in equation, or of the arrow of force in handwriting diagram. They are also linked to the strategies for correction.

For example, in Figure 1, the term of friction ($-\mu mg$) is missing in the erroneous equation. The cause of this error and its instruction are considered as follows:

1) A learner doesn't know the concept of friction itself, that is, doesn't know the rule R3 (Table 1).
Instruction: Re-teach the concept/definition of friction.
2) A learner is overlooking the preconditions of R3, that is, overlooking the fact that the block is touching the floor (r3-c1), or the fact the coefficient of friction is nonzero (r3-c2).
Instruction: Re-show the problem and indicate the corresponding part of the diagram.
3) A learner is missing the force which causes the friction, that is, missing the normal force (r3-c3).
Instruction: Proceed to the correcting strategy of normal force.
4) A learner doesn't think the block moves along the floor, that is, missing the relative velocity of them (r3-c4).
Instruction: This is the erorr of prediction of movement. So, out of the range of this paper. But, it may be useful to indicate the force which causes the block's motion.

Through such a consideration, the appearances of errors and their causes are classified as shown in Table 2. These are the Error-Identification Rules (EIRs), which are applied to the erroneous part of a learner's answer (specified by comparing with the correct solution), to identify the cause of error.

In Table 2, each error has its strategy for correction. Note that, it is not necessary to use EBS for every case. Of course, when other instruction method is more appropriate, it should be used. However, the aim of this paper is to clarify what kind of errors EBS is effective for, and how to estimate its effectiveness. For this purpose, we need to study the unnaturalness of physical objects' motion in simulation.

4 Criteria for Cause-of-Error Visualization

The identified error must be corrected. In this chapter, we formulate the criteria for judging whether an EBS is effective for the error. It means that EBS rightly indicates the cause of error and suggests the way of correction.

4.1 Motion and Forces

In EBS, it is the motion of physical objects (or their relationships) to be observed. Therefore, we classify the motions and connect them to the mechanical concepts they suggest.

Table 2. Error-Identification Rules (EIRs)

force	appearance	cause of errors	correcting strategy
external force/ gravity	missing extra error	missing knowledge of gravity (R0)	re-teach the concept/definition
		misunderstanding the problem (r0-c1)	re-show the problem and indicate the corresponding part
tension	missing	missing knowledge of tension (R1) overlooking the string (r1-c1) missing the force which causes tension (r1-c2)	re-teach the concept/definition re-show the problem and indicate the corresponding part proceed to the correcting strategy of that force
	extra	belief that string propagates tension (r1-c2) overlooking that motion loosen string (r1-c2)	re-show the problem and indicate the corresponding part indicate that tension is extra
	error	error of the force which causes tension (r1-c2) error of direction/magnitude (r1-c2/3)	proceed to the correcting strategy of that force indicate that direction/magnitude is erroneous
normal force	missing	missing knowledge of normal force (R2) overlooking the touch/attachment (r2-c1) missing the force which causes normal force (r2-c2)	re-teach the concept/definition re-show the problem and indicate the corresponding part proceed to the correcting strategy of that force
	extra	belief that normal force works (r2-c2) extra of the force which causes normal force (r2-c2)	indicate that normal force is extra proceed to the correcting strategy of that force
	error	error of the force which causes normal force (r2-c2) error of direction/magnitude (r2-c2/3)	proceed to the correcting strategy of that force indicate that direction/magnitude is erroneous
friction	missing	missing knowledge of friction (R3) overlooking the touching together (r3-c1) overlooking that coefficient of friction $\mu > 0$ (r3-c2) missing normal force (r3-c3) belief that normal force doesn't work (r3-c4)	re-teach the concept/definition re-show the problem and indicate the corresponding part re-show the problem and indicate the corresponding part proceed to the correcting strategy of normal force indicate that friction is missing
	extra	missing that coefficient of friction $\mu = 0$ (r3-c2) extra of normal force (r3-c3) belief that normal force works (r3-c4) extra of the force which causes friction (r3-c4)	re-show the problem and indicate the corresponding part proceed to the correcting strategy of normal force indicate that friction is extra proceed to the correcting strategy of that force
	error	error of normal force (r3-c3) error of the force which causes friction (r3-c4) error of direction/magnitude (r3-c3/4/5)	proceed to the correcting strategy of normal force proceed to the correcting strategy of that force indicate that direction/magnitude is erroneous
propagating force	missing	missing knowledge of force propagation (R4/5) overlooking the touching together (r4/5-c1) missing of the force which causes force propagation (r4/5-c2)	re-teach the concept/definition re-show the problem and indicate the corresponding part proceed to the correcting strategy of that force
	extra	belief that force propagates (r4/5-c2) extra of the force which causes force propagation (r4/5-c2)	indicate that propagating force is extra proceed to the correcting strategy of that force
	error	error of the force which causes force propagation (r4/5-c2) error of direction/magnitude (r4/5-c2/3)	proceed to the correcting strategy of that force indicate that direction/magnitude is erroneous
other	extra	impetus	indicate that impetus is extra

How does a human perceive and recognize moving objects? Though it is well known that their figurative characteristics (figure, size, texture, etc.) and composition (position, direction, symmetry, etc.) have great influence on the arising images, it is difficult to generalize them because they much depend on the cultural factors. Therefore, we limit our target to the physical world of simulation, in which things are thought in the sense of mechanics.

When observing an object to move, a human feels its motive 'force' working. Of course, this kind of 'force' is of naive impression and doesn't always correspond to the real force. But it appeals to human's intuition so much more. Bliss & Ogborn (1992) classified such naive concepts of force according to the stages of child development. Based on their findings, we consider the relations between the motions in EBS and the forces they suggest.

4.2 Motion of a single object

A moving object arises the feeling of force working. (e.g. A falling down ball suggests gravity.) Therefore, the object moving unnaturally in EBS is supposed to suggest the erroneous force acting on it. (e.g. gravity, friction etc.) Unnatural motions of a single object are classified as follows:

(a) Directions of both velocity and acceleration are opposite to the ones of correct motion.
(b) Direction of only velocity is opposite to the one of correct motion.
(c) Direction of only acceleration is opposite to the ones of correct motion.
(d) Directions of both velocity and acceleration are same as the ones of correct motion.

Here, it is assumued that human can distinguish at most the qualitative difference of velosity or acceleration of an object in motion [Hirashima et al. 98, Horiguchi et al. 99].

For example, in case (a), when a learner observes an object moving in the opposite direction to her/his prediction (which is correct), she/he will recognize that the force is missing which acts in the predicted direction, or that the force is extra which acts in the present direction.

Table 3 shows the relations between unnatural motions and the errors they suggest. They are called Criteria for Cause-of-Error Visualization (CCEVs).

4.3 Relative Motion of two objects

Moving plural objects also arises the feeling of force working. We limit to two objects. When observing two objects moving together, the force maintaining their relative motion is felt. (e.g. A moving dolly pulling another one connected by string suggests tension.) Therefore, two objects relatively moving in unnatural manner in EBS are supposed to suggest the erroneous force interacting between them. (e.g. tention, normal force etc.) Unnatural relative motions of two objects are classified as follows:

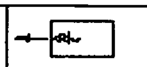
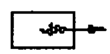
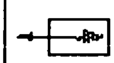
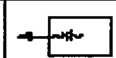
(e) Two objects are closing with each other, which are connected by string. (String shrinks.)
(f) Two objects are going away from each other, which are connected by string. (String stretchs.)
(g) Two objects are overlapping each other.
(h) Two objects are parting from each other, which are attached together.

For example, in case (g), when a learner observes such unnatural relative motion, she/he will recognize that the normal force is missing or too small which interacts between two objects.

Table 4 shows the relations between unnatural relative motions and their suggesting errors. They are also called Criteria for Cause-of-Error Visualization (CCEVs).

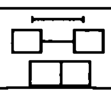
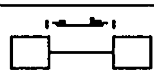
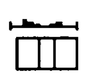
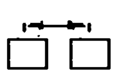
Note that, all of the motions in Table 3 and 4 have at least some kinds of qualitative difference from the correct motions. This is because, however precisely an EBS indicates the error, it isn't effective unless a learner recognizes it as 'unnatural.' The difference is judged with Criteria for Error-Visualization (CEVs) [Hirashima et al. 98, Horiguchi et al. 99].

Table 3. Criteria for Cause-of-Error Visualization (CCEVs) (for single object)

motion		difference	suggesting errors
correct motion		–	–
motion (a)		velocity: opposite acceleration: opposite	missing of the force opposite to moving direction ⊙ extra of the force same as moving direction ⊙ larger of the force same as moving direction ○ smaller of the force opposite to moving direction ○
motion (b)		velocity: opposite acceleration: same	missing of the force same as moving direction △ missing of the force opposite to moving direction ⊙ extra of the force same as moving direction ⊙ extra of the force opposite to moving direction △ larger of the force same as moving direction ○ smaller of the force opposite to moving direction ○
motion (c)		velocity: same acceleration: opposite	missing of the force same as moving direction ⊙ extra of the force opposite to moving direction ⊙ smaller of the force same as moving direction ○ larger of the force opposite to moving direction ○
motion (d)		velocity: same acceleration: same	missing of the force opposite to moving direction △ extra of the force same as moving direction △

note 1. ⊙ : able to suggest the error by itself with great effect
○ : able to suggest the error by itself with small effect
△ : need to be modified some parameter(s) to suggest the error
note 2. The error of force in direction is divided into the missing of the force of correct direction and the extra of the force of incorrect direction.

Table 4. Criteria for Cause-of-Error Visualization (CCEVs) (for two objects)

motion		undesirableness	suggesting errors
correct motion		constant distance	–
motion (e)		closing spring shrinks	extra/larger of the tension ⊙ extra/larger of the propagating force ○
motion (f)		going away spring stretches	missing/smaller of the tension ⊙ missing/smaller of the propagating force ○
motion (g)		overlapping	missing/smaller of the normal force ⊙ extra/larger of the normal force ○ missing/smaller of the propagating force ○ extra/larger of the propagating force ○
motion (h)		parting from each other	missing/smaller of the normal force ○ extra/larger of the normal force ⊙ missing/smaller of the propagating force ○ extra/larger of the propagating force ○

note 1. ⊙ : able to suggest the error by itself with great effect
○ : able to suggest the error by itself with small effect
note 2. The error of force in direction is divided into the missing of the force of correct direction and the extra of the force of incorrect direction.

5 Examples

In this chapter, we illustrate the process of identifying the cause of error and generating the EBS which indicates the error. The example problem is shown in Figure 2.

5.1 A Simple Case

First, the solution (correct equation and diagram: Figure 2a) is generated by problem-solver. Then, it is compared with a learner's answer (Figure 2b) to specify the erroneous part. In this case, it is the erroneous value (too large) of tension beside block m2. Secondly, EIRs (in Table 2) are applied to identify the cause of error. It is identified as the error of magnitude of tension. According to Table 2, the correcting strategy of this error is to indicate the fact. Then, CCEVs (in Table 3 and 4) are applied, to find that the motion (g) satisfies this demand.

Based on the erroneous equation of Figure 2b, the EBS shown in Figure 2c can be generated, in which block m2 moves faster than its normal case, consequently the string shrinks. This unnaturalness is equal to the one of motion (g). Therefore, this EBS is judged to satisfy the instructional demand, and shown to the learner.

5.2 A Complicated Case

Consider the erroneous answer of a learner in Figure 2d. In this case, the erroneous part is the erroneous direction of friction acting on block m2. By EIRs, the cause of error is identified as the error of direction of friction, and the correcting strategy is to indicate the fact. Since the error of force in direction is divided into the missing of the force of correct direction and the extra of the force of incorrect direction (see note 2 of Table 3), the motions (a), (b), (d) satisfy this demand.

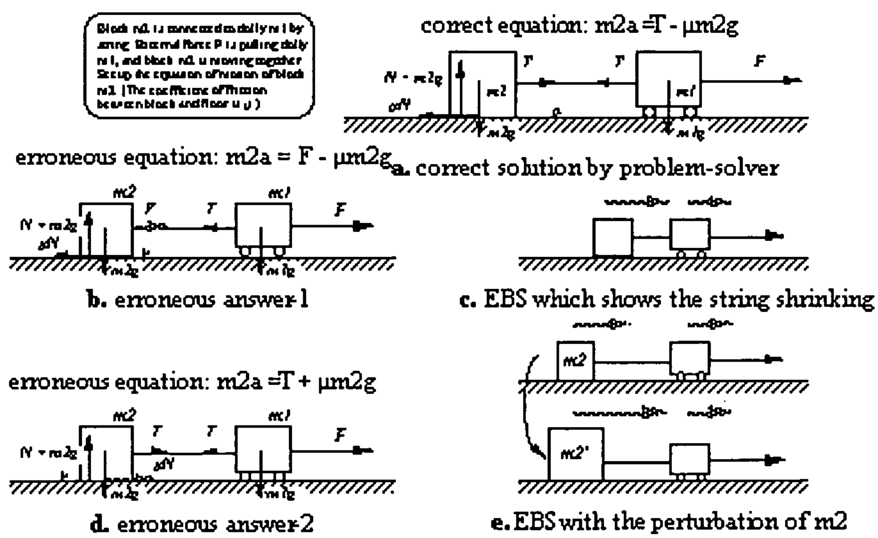


Figure 2. Example Problem-2

Based on the erroneous equation of Figure 2d, however, it is impossible to generate the EBS which contains the motion (a) or (b). In addition, even when the EBS containing the motion (d) is generated (it is possible), it causes the unnatural relative motion (e), which indicates another error. In fact, the EBS, in which block m2 is closing to dolly m1 (the same as Figure 2c), strongly suggests the error of tension. This misleads a learner.

Therefore, in this case, the EBS must be modified to precisely indicate the identified error. Perturbing the mass of block m2 is a promising method. When the mass m2 increases, in EBS, the velocity of the block increases (Figure 2e). This is a strange change of motion. Observing this, a learner may think some physical amount is wrong which concerns the mass m2. She/he may notice the erroneous friction acting on block m2.

As for the EBS of Figure 2e, the difference from the correct simulation is not so much clear and reliable as the EBS of Figure 2c. Instead, it provides precise information for correcting the error, while the EBS of Figure 2c doesn't. In general, plural EBSs can be generated from one erroneous equation. The best should be chosen according to the purpose.

6 Concluding Remarks

In this paper, we proposed a method of creating effective counterexamples by using Error-Based Simulation. The effectiveness of EBS is judged mainly from the viewpoint whether it provides sufficient information to recognize the cause of error and correct it. The mechanism for identifying the cause of error and for

generating the EBS which satisfies the instructional demand was also proposed. We are now implementing the mechanism. The experiment to evaluate our method is planned.
Our future works are as follows:

1. *Cooperation with other instructional tools:* Of course, EBS isn't sufficient for all of the error correction in Table 2. It must be studied to use other instructional tools (textbook, normal simulator etc.), and to coordinate them with EBS.
2. *Refinement of the problem-solving model:* Our model for problem-solving is very simple, so the range of the error it covers is limited. We are going to refine the model, especially considering the process in which a learner qualitatively predicts the motion of mechanical system.
3. Consideration of conflict among CCEVs: As is noted in section 5.2, the effects of plural unnatural motions sometimes conflicts each other. One unnatural motion may invalidate the effect of other unnatural motion. Therefore, it is necessary to set some kind of preferences to CCEVs.

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An Interactive Game System to Stimulate Word Associations

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We present here an interactive game system designed to stimulate user's knowledge associations between words. The system is based on a word-association television game called "Himitsu no Tsunagari". This game uses two different words and an association word. Each player is given a word, and must guess the other word and the association word to win the game. Our system allows person-to-person matches and person-to-computer matches. We believe that our system stimulates the users' creativity and their ability to form associations. Our system also acquires knowledge of word associations from game records. As more and more games are played, the system's knowledge of associations grows, and so does its ability to compete with the user.

Keywords: **Educational game, Interactive learning, Knowledge acquisition, Word association.**

1 Introduction

Many games have been designed to enhance various human abilities. Saeki [8] has pointed out that educational software needs to motivate learners in order to attract and retain their attention. If only its appearance is attractive, learners tire of the software soon. One approach developed in our lab to motivate children is the "Instruction Assisted Computer" (IAC) paradigm [4]. In this paradigm, the system is given a passive role and the children are put in the driver's seat. The result is that the familiar roles of teacher and pupil are reversed, and it is the children who end up 'teaching' the computer. To date we have successfully developed and studied several different systems using this paradigm [3][6][8].

Associations between words and concepts form a major dimension of human knowledge. Stimulating these associations can greatly influence concept formation and increase one's problem-solving skill [1][9]. Models based on association networks have been used for vocabulary acquisition [5] [7], and many association word-games have been developed [2].

In this paper, we describe a system to play an association game called 'Himitsu no tsunagari'. This game requires the player to think of several concepts at once and look for associations between them. We believe that this stimulates various associations inherent in the user's knowledge. Our system allows a user to play with another user (on the web, so that two users do not have to be in the same place), or with the computer. It also has a knowledge acquisition module, which analyzes the associations created in each game. These associations are added to the system's knowledge base, and result in a gradual improvement in the system's performance. In the rest of this paper we describe our system and the results of our initial experiments.

2 A Brief Introduction to Himitsu no Tsunagari

Himitsu no Tsunagari is a television game show in Japan. It is an association game using two different words (called 'keys') and another word that is associated with both keys (called a 'link'). There are two teams and a judge. Behind each team, a key is hidden (see Figure 1), so that each team can see the opponents' key, but not their own. Neither team can see the link. The goal of the game is to find their own key and the link. Each team takes turn guessing answers based on the visible key and the past guesses of the other team. The judge provides an evaluation of each guess ('correct', 'close', etc.). For example, in the second row in Table

1, Team B can infer that their key is something "yellow" from Team A's previous answer.

The associations between the keys and the link are not limited to those semantic or conceptual, but can be of any kind. For example, in Japanese "Niji" serves as a link between the keys "14 o' clock" and "rainbow" because both keys are homonyms of "Niji".

3 Design and Implementation of the system

Here we describe the interactive system for the Himitsu no Tsunagari game. We first describe the goals of our system. Then we explain the rules of the computer game, which are a little different from those of the TV game. Thirdly we present an outline of our system and discuss the relations among various modules. Fourthly, we describe the reasoning and knowledge acquisition modules in more detail. Finally, we describe the interface of our system.

Table 1. Flow of a game (Topic : keys - banana and strawberry, association - fruit)

Team	Visible key	Answer (Key)	Answer (Association)
A	Banana	Sunflower	Yellow
B	Strawberry	Lemon	Sour
A	Banana	Grapefruit	Fruit
B	Strawberry	Pineapple	Fruit
A	Banana	Raspberry	Fruit
B	Strawberry	Banana	Fruit

3.1 Design goals of the System

In order to allow many people to play and enjoy our system, we set the following design goals:

–The game can be played on the Web.
–The computer can be one of the players.
–The system has an easy-to-use interface.

3.2 The rules of the computer game

We clarified and added some rules to the TV game rules, as explained below.

- The game is played with two players and one judge
- At the beginning of a game, each player is given a key and the judge is given both keys and the link.
- The judge evaluates each guess as 'correct', 'near miss, 'incorrect', or 'strange'.•
- Each player is allowed 90 seconds for making a guess.
- The game is finished when the judge declares the guesses of the key and the link as correct.

3.3 Overview of the system

The structure of our system is shown in Figure 1. There are five modules in it: game server, user interface, knowledge acquisition, reasoning module (making guesses), and knowledge database. The game server is responsible for sending the keys and the link to the players and the judge, and for passing messages (guesses and evaluations) between the players and the judge. The words used in the game and their associations are saved in the knowledge

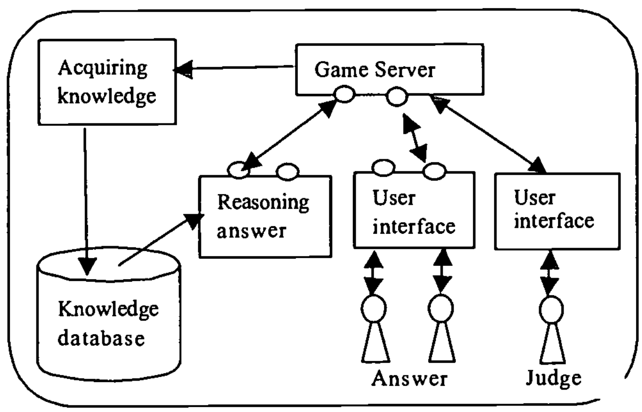


Figure 1. Structure of the system

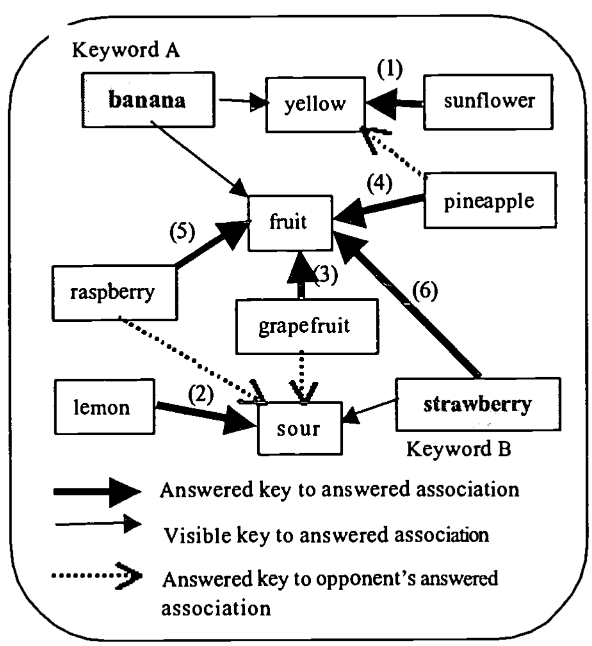


Figure 2. Association network from a game.

database. This knowledge is used to make guesses when the computer is one of the players.

3.4 Acquiring and Reusing Knowledge

We describe here our approach to acquiring knowledge about word associations from past games, and using this knowledge to make guesses in subsequent games.

3.4.1 Knowledge acquisition from past games

From the record of a game we can make an association network (Figure 2). It is difficult to say from the record which guesses of the opponent were useful for a player in making his or her own guesses. For example, when the opponent's guess seems quite unrelated to the visible key, a player may just disregard it. However, we assume that the link and the key in each player's guess are associated. We also assume that the link in each player's guess is associated with the key visible to that player. So we add <guessed-key, guessed-link> (➡) and <visible-key, guessed-link> (⟶) to our set of associations in the knowledge base. We call each of these pairs an "association pair", and the network created by all the association pairs an "association net".

3.4.2 Reasoning Module: Guessing the key and the link

As mentioned above, we assume that the link guessed by a player is associated with the visible key and the guessed key. For this guess we make two assumptions: the guessed link is correct or incorrect, and the guessed link has something to do with the hidden key. For example, if the opponent guessed "the key is 'apple' and the link is 'red'", and it was judged incorrect, a player can infer that the opponent's visible key (and the player's hidden key) is associated with red and the correct link is not "red". From these two pieces of information we can search for plausible answers in the association net (Figure 3). Every time the opponent makes a guess, the computer searches the association net and adds a certain weight to each plausible association pair. When it is the computer's turn to make a guess, it selects the association pair with the highest weight.

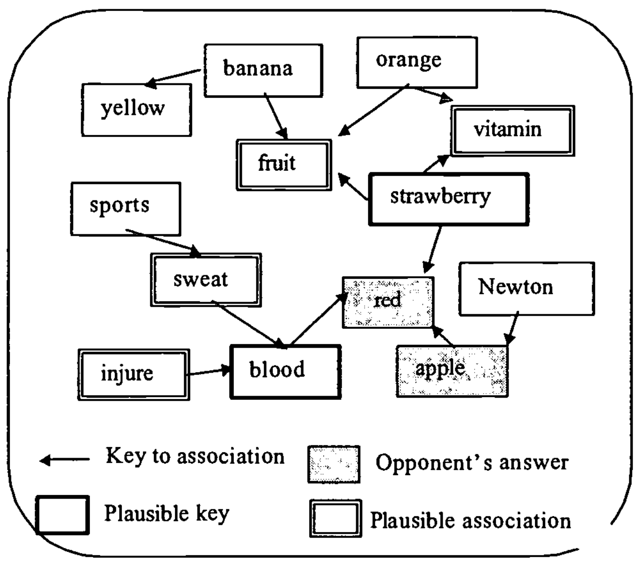


Figure 3. How to search for plausible answers

3.5 Interface

There are two displays, one for the judge and one for the players. They differ only in the input area. The player-interface displays the visible key and the history of the game (the player's guesses, the opponent's guesses, and the judge's evaluations), and has areas for entering the guessed link and key. The judge-interface is similar except for the input area. Instead, it has eight buttons (four each for the key and the link) at the bottom of the screen to evaluate the players' guesses. There is a time limit of 90 seconds, after which an answer is sent automatically.

4 Experiment

We tested our system with 10 undergraduate students in the Computer Science Department. In the beginning, we explained how to play the game with various topics and a sample game. Then subjects were matched to a computer to play the game using ten topics for two hours. Assistants judged the games. Subjects sometimes thought deeply and sometimes seemed to hit upon an idea quickly. We acquired about 1,400 answers. Here is a result of one game (see Table 2).

After playing the system, we let the subjects explain from which words they guessed the answers. We used their explanations to determine from how many words an answer was guessed • we call this the 'base-words number'. For example, "wiener" was guessed from "coffee" and "hotdog", so the base-words number is 2. The average base-words number was 1.4. This result shows that users try to consider more than one word in playing this game.

Table 2. An example, "Wiener & Twins". Both concepts also called "sohseiji"inJapanese

Turn	visible key	Key	Association
Computer	Wiener	American	Coffee
Sujject	Twins	Haliwood	Shuwalzneger
Computer	Wiener	Ketchup	Hotdog
Sujject	Twins	No	No
Computer	Wiener	Salami	Sausage
Sujject	Twins	Wiener	Sausage

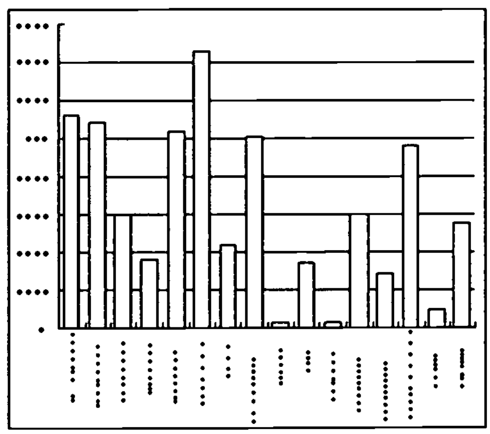
Some subjects tended not to answer within 90 seconds. Such subjects were found to have a higher base-words number than those who answered in time.

We categorized the associations into 16 groups (Graph 2), most of them from Togawa's classification. Superior, inferior, instance, synonym, same, emotion (<magic, muse>), character (<apple, red>), character2 (<Wright, airplane>), component (<sausage, pork>), inclusion (<apple, pineapple>), junction (<sun, flower>), place/time, phonic, verb, target (<knife, apple>), ellipsis (<wolf, liar>wolf boy lies a lot). Synonym was the most frequently guessed category. Ellipsis association represented 5% of the guesses. We think that playing with the system stimulates many kinds of associations.

We also gave a questionnaire after playing the game. In spite of its free answer form, most players answered that they enjoyed thinking and the moment of hitting upon an idea.

5 Conclusion

We described an interactive system using the Himitsu no Tsunagari game. In this game a user can play against either other users or a computer player. The computer uses the knowledge acquired from past games. It improved itself by acquiring knowledge from game records. Users tried to answer using associations to 1.4 words on average and in various categories. In addition, they said they enjoyed thinking about the answers in the experiment. We believe our system stimulates users' ability of associating words. Since many games were played, the computer acquired sufficient knowledge to compete well against users.



Graph 2 Categories of associations

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Applied the Gray Relationship Matrix and Learning Obstacles Analysis on the Discovery Teaching

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At recently year the research of teaching method are trending to request the student for active learning, to avoid the student to learn the stuff knowledge. Therefore the number of researchers in the constructivism and cooperative learning etc fields are many. Even now how to estimate the student's learning attitude belong an active type, is a big problem. In our research, we recur to the simple method, adopt the discovery teaching. Because under the discovery teaching, the student does not only use his ground knowledge, but also need face the problem's stimulation and bring the solution. This method can mostly saturate the today's teaching trend. But how to analyze the student's learning obstacle area and supply the explanation to help him cross over the learning barrier is a net bottle in the discovery teaching. In this paper, connect the concept graph and the gray decision-making to issue the gray analyzing method of learning obstacle. This method has a flexible ability to point out the area of learning obstacle, it also can infer the student inbuilt concept or relationship on his knowledge structure. Finally, according to the expert's experiments rule to clearly distinguish the core of problem. Then the system obeys the inferring rules to bring the explanation and the similar question to stimulate the student to build his whole knowledge. This learning cycle will continue until the student completely finishes his learning.

Keywords: **Discovery Teaching• Gray Theory• Concept Graph• OO**

1 gray relational concept graph

a. The design of cognitive structure

Induct the student to learn the material, not only implant him a located knowledge, but also hope he can actively learn or construct the knowledge. Therefore, our system want to stimulate the student, and hope he use his langue or letter to descript his thinking. It like he uses his symbols to review the content and build his cognitive structure. Therefore in our system, our chapter designing does not like traditional, we use the proposition to build concept graph.

Table 1 the relationship matrix

relation / node	Node 1	Node 2	Node 3	Node 4	Node 5
Node 1					
Node 2					
Node 3					
Node 4					
Node 5					

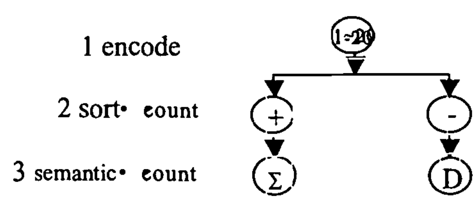

Fig. 1 Concept Garph

b. Relational concept graph

From the cognitive structure graph we can understand that the relation be assembled by node linking to other node, of course each relation also has its particular mean. And in our system the question is based on proposition, then accord with the problem' s subject the expert can distribute the weight to each node and each relation. These data can be consisted a matrix, and we call this matrix as the conceptual relationship matrix.

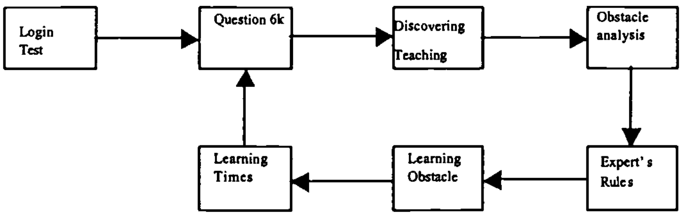

Fig. 2 System graph

As Fig.2, when the student log into the system, the system will give him some questions are selected from the question database. After the student transmit his answers to system, the system will start to analyze his learning obstacles. Of course, the student' s does not have much time for studying, the system hardly collect the enough data for analyzing by statistical recursive method. Because the statistical recursive has some limited: large data, the data distribution must like normal and the variants cannot too many. Consequently, the only way we can elect to adopt the gray theory to reduce the analyzing data. This matrix is called the gray relational conceptual matrix.

2 Gray relational learning obstacles analysis

The gray decision making system is meaning that the system includes some gray element (uncertainty or incomplete factor). In general case, the decision making space X is constituted by event sets S• {Sij} and efficiency sets R..

After the student interact with system, the system can collect his data to assemble the gray relationship' s matrix. The analysis method explains as following.

Table 2 the relationship matrix

relation / node	Node 1	Node 2	Node 3	Node 4	Node 5
Node 1	0	0	0	0	0
Node 2	0	0	0	0	0
Node 3	0	0	0	0	0
Node 4	0	0	0	0.5	0.5
Node 5	0	0	0	0.2	0.8

Table 3 the gray relationship' s matrix

relation node	Node 1	Node 2	Node 3	Node 4	Node 5
Node 1	0	0	0	0	0
Node 2	0	0	0	0	0
Node 3	0	0	0	0	0
Node 4	0	0	0	1	1
Node 5	0	0	0	0.2/0.8	1

1. According to the Grey formulate, can translate table 2 to table 3. The system can calculate each node' s average weight, and according these values to arrange their ranking.

Table 4

Node 1	Node 2	Node 3	Node 4	Node 5
0	0	0	1.25/2	2/2

2. If the nodes weight higher than the threshold value 0.3, the system can find the weight at node 4 and 5 are higher than 0.3, the system define these nodes are the learning obstacle nodes.
3. At the same time, according to the relation' s matrix (table 2), the relation 4-5 is 1 higher than • •cut (0.3) is the relation of learning obstacle.
4. According to the expert' s rules decide expanding or reducing the learning obstacle area.
   Use the aforementioned logic the system can reduce the relation 5-4 and relation 4-5 to infer the learning obstacle area is node 5

3 Conclusion

On the teaching the most afraid thing is to induct him learning the inert knowledge. Therefore, in all teachings methods the discovery teaching is the only one can avoid this problem that is why we adopt the discovery teaching to develop our system. But how to break through the discovery teaching' s net bottle, our issue are: integrate the concept graph and gray decision-making system to develop the gray analyzing method, and use it to discover the student' s learning obstacle. This analyzing has an ability to point out the learning obstacle area, and enhance the inferring ability to find the student' s learning obstacles or the incompletely knowledge, then pass through the expert' s rules, the crossing analysis method can find the problem kernel. Then system rely on this result to elect the problem saving content, let the student can learn it again and rebuild his knowledge structure until he can construct the whole knowledge.

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Collaborative Learning vs Cognition

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A study has been conducted in the course of development of a Web Based PBL System in order to design an effective and efficient tool for learning through online discussion. This paper deals with the results of the experiment conducted using web board for discussion. Discussion was focused on the cognitive maps produced by the group members. The members of a group produced cognitive maps after reading the given text material. We have experimented with both heterogeneous and homogeneous ability groups. The outcome of the experiment shows the changes in the understanding of the participants on different concepts and subsequent changes in the modified cognitive maps after the discussion. Analysis of discussion protocols recorded on the web board revealed the factors responsible for the changes in cognition. It has been found that the heterogeneous ability groups could be more successful if the learner's motivation and interest are high.

Keywords: **Collaborative Learning Group, Cognitive Maps, On-line Discussion, Problem Based Learning**

1 Introduction

We have developed a web-based system for problem-based learning. We have conducted an experiment in order to find out a suitable method for online group discussion during PBL. In an article [1] it is mentioned that a good conceptual model of the problem system along with the strategic knowledge to generate appropriate solutions and procedural knowledge to carry them out will result in more successful problem solutions. When complex problems are solved by groups of people, sharing a similar mental model of the problem and system will facilitate solutions. In our two earlier publications, we have reported the effectiveness of cognitive maps as a tool [2] and the use of web board [3], for discussion on the web.

Learning is multistage process and results into formation of higher level mental constructs known as Cognitive Maps. Oriented learner gradually makes a transition from an intelligent but mostly passive receiver to an active information collector and finally to a researcher. Different kind of cognitive activities are performed during different stages. Learning results into mental encoding of knowledge which is internally represented by multidimensional higher level mental constructs known as Cognitive Maps [4]. Many researchers have considered concept mapping as the tool for learning in the distributed learning environment [5] and [6]. It has been reported by Moen & Boersma [7] that concept mapping is a tool that contributes to the efficiency of knowledge construction.

We did the experiment with both homogeneous and heterogeneous groups. In case of homogeneous groups we have considered participants having almost equivalent level of knowledge regarding the topic of study. For the heterogeneous groups one of the participants had specialized knowledge about the topic for study. In this paper we have considered the learning outcome of a typical heterogeneous group. This group consisted of three members where one of the participants has specialization in Linguistics. The topic for study and discussion was Language in Teaching, an article from a book on Theories of Learning.

As pointed out by Billinghurst and Weghorst [8], one of the difficulties in studying cognitive mapping is the problem of extracting an external representation of an individual's internal map. By definition a cognitive map is highly subject-specific and, although individuals often record the same things in their cognitive maps, there is no evidence that they record them in the same way. Golledge [9] identifies four distinct methods for extracting environmental cognition information: experimenter observation of subject behavior, historical reconstruction, analysis of external representations and indirect judgment tasks. In the present study subjects' cognitive maps were assessed through subject self-reporting.and.analysis.of.external.representation.

2 Research Questions

How effective is the collaborative learning by a heterogeneous group and what are the conditions of successful outcome?

3 Procedure

The group under consider consisted of three members. Each of them was provided with the article on Language in Teaching. Details about the members as follows:

Nicknames of Group Member	Gender	Location	Area of Specialization	Profession
Rose_Jasmin	Male	Africa	Mechanical Engineering (Ph.D.) & Educational Technology	Teacher
Rajni	Male	Europe	Science & Linguistics (Ph.D.)	Researcher
Ajisai	Male	Asia	Electrical Engineering (Ph.D.)	R &D staff in a company

The participants studied the article and came up with the cognitive maps based on their self-understanding of the article. On a particular day the discussion took place using the web board on the Internet. The discussion was focused on the cognitive maps made by the participants. Half an hour before the discussion the author (Nickname: Mita) posted each other's cognitive maps to the group members. This was done either by posting as email attachment or by uploading on the web page. Participants were given fictitious names for discussion so that their identity remains unrevealed. This also helped the participants to give their comments during discussion without any biases. After the discussion participants were given a questionnaire consisted of questions on their preferences for the conditions for discussion. Also participants were allowed to modify their cognitive maps as per their new understanding. Some of the participants modified their maps and sent to the researcher.

4 Protocols of Group Discussion

In one of our earlier research [3] we have reported that the use of web board has been found to be more effective than chat room for discussion on the Internet when topics involving deep thinking is involved such as cognitive maps. Use of chat room for discussion involving higher order thinking produces more cognitive load as a result group members were unable to concentrate and lost the track of thinking.

Following is the excerpts from the record of discussion protocols of a typical heterogeneous group where discussion took place using web board. Participants were grouped as heterogeneous or homogeneous according to their previous knowledge about the given topic. All the participants volunteered for participating in the experiment.

Ajisai: ajisaisai speaking from earth station. What is the weather at space there? "Writing questions: employing language in learning "Regarding "purpose", why it is centered at students?
Rajni: I'm looking at Rose's map (if it's a map :)) My observations: 1. 'Writing Question' as a title is misleading as it highlights a rather small section of the paper. The sub-tile of course reinstates the main topic. But it's creative anyway! 2. Dividing the content of the paper into three categories -- Purpose, Criteria and Examples -- is, to my mind, more as a result of what a map _should_ have

rather than what the paper actually deals with 3. PURPOSE: except the 2nd point, no other point is derived from the discussion in the paper 4. CRITERIA: the 2nd point is not from the paper 5. EXAMPLES: This section doesn't do anything for me, the examples don't relate to the points raised earlier 6. I agree completely about the limitation of concept maps in general (what are they anyway?) -- my strongest objection to any chart is that it involves oversimplification and thus inaccurate teaching/learning/ understanding. E.g., it's rather messy and difficult to show the bad points of a particular system. What do others think? May be Rose can develop on this idea and try to incorporate certain inadequacies of maps into maps!
rose_jasmin: *Wait a minute, the paper gave an assignment ONLY on writing questions, so I thought the whole thing is leading to that!* *Wait, responding. Purpose, all three ideas CAME or got sprung from the paper. It is BRAIN MAP, not an input map. See, a brain may think differently than you give input. It may ignore some points and highlight some other remotely mentioned. Should one stop the meandering process of the brain?*
rose_jasmin: *How is it possible for a person to prepare such an elaborate map? Two parts, one and two. God!* *No,I admit my map is not even an apology of a map. I already said that, I needed someone to khurocho (scratch) my brain and get that out of it. hats off to Rajni map! I do smile at your map:):):) and cry at my own :(:(:(:(* *Rajni's map is so elaborate as if I am entering her (or his brain! God, not easy to get into it!* *One question, can I use this brain map as an example of a wonderful mapping to my students and in the Book Educational Technology? Permission requested.*
Rajni: Rose you asked about depicting meanderings of your mind -- I wish I could that -- you might have gotten a very interesting map! Seriously, I think it's an imp point. If a map is supposed to be an aid then you can't do whatever you fancy. I believe that any piece of academic writing should be, in the final analysis, "usable" -- it's a dirty word but useful (!). If it's supposed to be creative, meanderings should be captured. In fact, even such meanderings in academic circuits might find some use for someone someday. Next point about brain map: I don't know if this is a serious terminology of just been coined here today in this discussion. If it is then I don't know how to decide between a creative map and an "usable" map. Thanks for the comments.
Ajisai: Nice drawings!!! Very complicated. Feeling sleepy......haaaaa......
rose_jasmin: *My comments are on your concept of the concept map itself. Yes, I agree, don't simplify it and don't look out the expected. A map is that someone perceives.* *Not just nice. Million compliments to the drawings. I am over-awed! Ya, but it is the complicacy that needs to be observed how detailed a person is conceiving.*
rose_jasmin: *I closed the book before drawing maps, what was correct, to close or not to close the book?* *What time? Why sleepy? Nobody else came. ??*
Rajni: My guess is that it can't be otherwise. This paper, if it has any value at all, mu st be talking about the student learning (and not, e. g., the teacher herself learning). In fact in the Flanders's analysis part (which according to me is a separate monster altogether and nothing whatsoever to do with the general topic of the paper) the author herself confuses the Teacher (=T) and Student (=S) response. E.g. point no. 8 and 9 are the only ones, which measure S response. So Rose's (unintentional?) depiction of the purpose as S centered is to vote affirmatively (inter-alias my objections to his summary in general) to try to salvage this hopeless paper.
rose_jasmin: *Yes, it is all about learning by all concerned .The one by Ajisai is clean and simple. It is a flow diagram.*

Mita: At least we need your response yes rose why purpose is centered around students
rose_jasmin: *Because students reside in my brain perhaps. I think of that direction only.*
Rajni: is -- I hated doing it because it means I'm glorifying the paper which, as I've expressed very unambiguously, is crap. The complication is due to my efforts to incorporate the bad points of the paper into the map as well. I find a lot of similarity in Ajisai's map but my critique of maps in general stands: It over glorifies bad papers and it oversimplifies complicated concepts. Specific points about Ajisai's map: 1. It's a very good summary of the paper but does it aid in understanding the paper? I'm not so sure if it does. E. g., 'What is Language?' is something we must know but it need not make one a good teacher. Rather an effective use of language is what makes a good teacher (according to me). And effective use can be made by learning the _techniques_ rather than the definition or description of what a language is. So the 1st alternative choice in this map needs either removing or modification. However if concept map is supposed only to summarize, it's correctly done. 2. There are further divisions within understanding and description of language which the author points out (although almost completely incorrectly) that can be incorporated in this flow chart. 3. Use of Language: Looking at the 3 daughters of this alternative one cannot know how can language be used as a weapon or specially or restrictedly -- further levels are needed. But again, a good summary. 4. I don't quite agree that one way of evaluating is by talking. It might give a wrong impression to anyone who's not familiar with the paper. As I've pointed out in my map -- 'Teacher's Talk' is a misnomer and only reflects the author's childhood trauma! I think F's analysis is classroom evaluation as the it contains T and S evaluation and other factors (social) which are part of the classroom/ school rather than the T talking. So this needs clarification. 5. I agree with most other things in this map as I think it captures the intended meaning of the paper -- again, rescuing a bad paper
Ajisai: I in fact don't know what I did. I just summarized the paper. grrrrrr....... too much sleepy let me go.....
Rajni: No problem. It's good that you don't know what you did -- the paper is immensely forgettable. Why sleepy? Did you have too much beer? About your earlier comment on my map: 'multiple heads' because the paper talks about Language, Evaluation and Questioning but the title mentions only the first. That's why the mismatch. It reminds of the pictures of gods and goddesses of some religion that I've seen -- you can't make out which head is more important. You can call it 'multiple heads syndrome' or MHS for short just to appear technical!

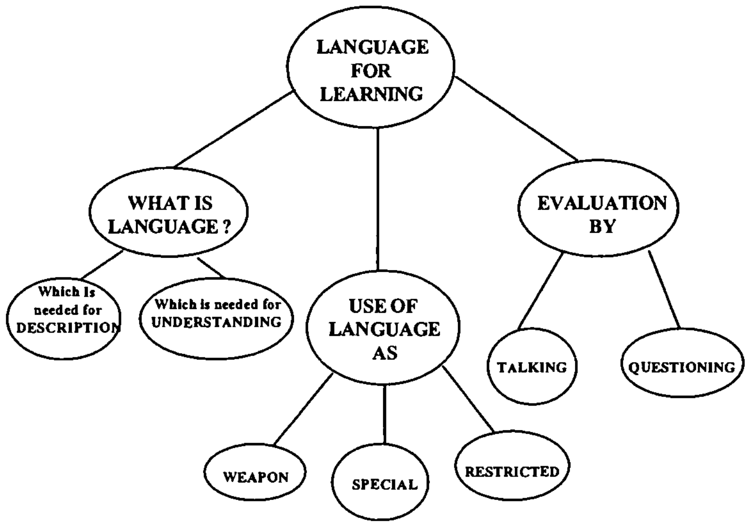
From this discussion it is clear that Ajisai certainly was not enthusiastic about the discussion. He could not keep track of the discussion by two members. He seems to have forgotten the contents of the study material. Also he did not made any preparation for participating in the discussion.

Rose_Jasmin was well motivated to learn more from Rajni. He was very much impressed by the cognitive map of Rajni. He was ready with his questions, which he wanted to ask other group members and the facilitator (Mita).

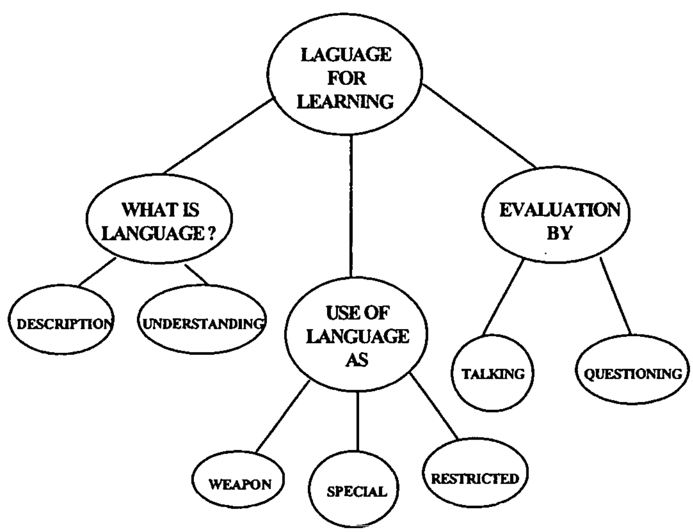
Rajni gave an elaborate explanation in response to all the queries made by other participants. His discussion shows a very deep understanding of the concepts. He tried to collaborate with other participants especially Rose_Jasmin by share his ideas with them.

5 Cognitive Maps: Before & After

In the particular group under consideration, participants: Ajisai made minor modifications in his cognitive map after the experiment. Which shows that he did not actually gained from the discussion or may he was reluctant to make major changes. Also it could be possible that he never took the task seriously or did not find himself knowledgeable enough to be able to participate actively in the discussion. His maps were in fact very simple and show that he has cognized the content of the article at a superficial level. Ajisai's cognitive maps are:



Cognitive Map: Before Discussion



Cognitive Map: After Discussion

Rajni did not find anything to be modified in his cognitive map and Rose_Jasmin modified his map drastically. It was interesting to find that before the discussion Rose-Jasmin thought that it is enough to represent his cognition only by using words. Later after the discussion he realized that visual representation of thought is better in a pictorial manner, which is also easy to recall the concepts and the relation among them at a later occasion. His cognitive maps are given as follows:

Writing Questions: Employing Language in Learning

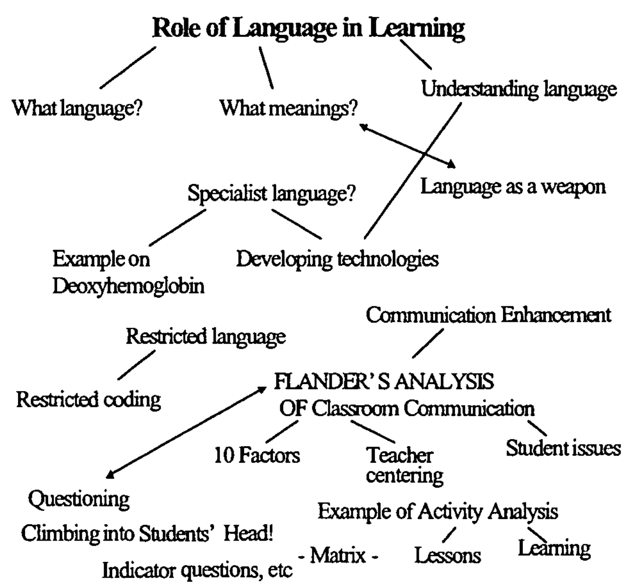
Purpose: To activate the students and to enrich their learning experience
: To use language to advantage in the learning process.
: To employ the vocabulary that they are used to in understanding.

Criteria: Questions to be relevant to the learning needs and to clarify the concept
: To diagnose and remedy the learning problems of a learner
: To employ language as a weapon and as a stimulant for teaching
: Words need to be used as are understood in specialist language.

Examples: Interesting examples include the teaching of oxy and de-oxy hemoglobin
in human body arteries and veins.

Discovering the components of a machine, say a lathe machine by questions and by employing language cards for different components, etc.

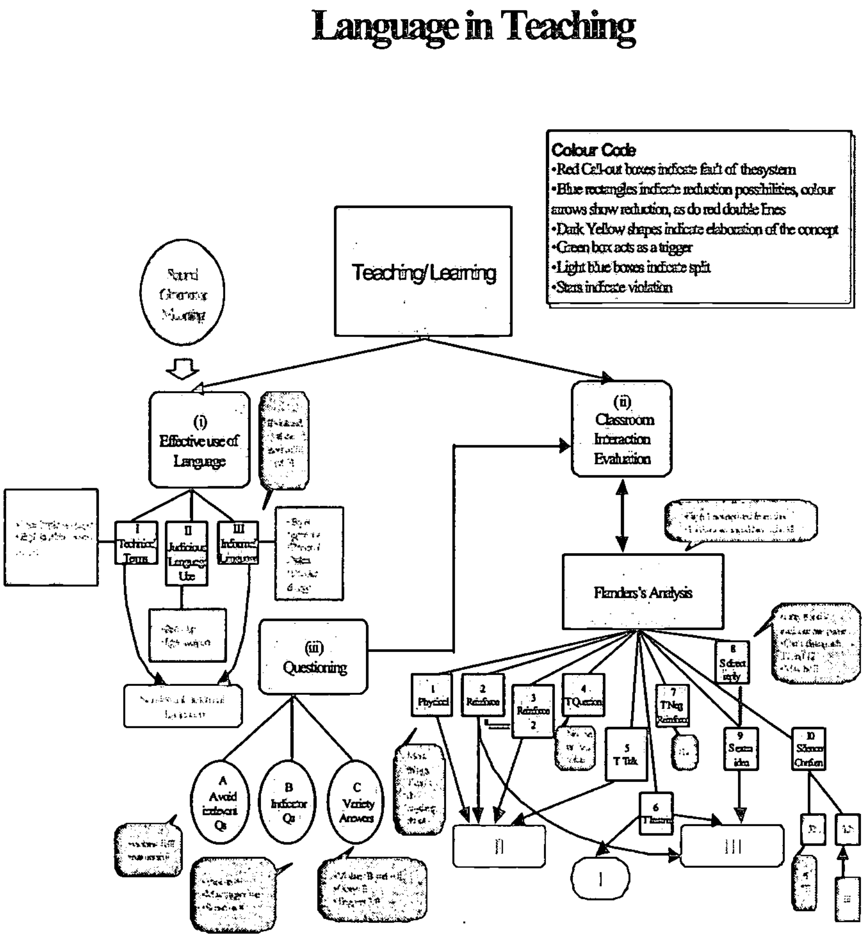
Cognitive Map: Before Discussion



Cognitive Map: After Discussion

6 Discussion

You may find from the discussion protocols that Rajni and Rose_Jasmin took part in the discussion seriously. Ajisai was not so serious. Later we found out that at the time of discussion he was engaged in another experiment in his laboratory and was running between his office and laboratory for the discussion. Therefore, Ajisai was unable to get the benefits out of the discussion. This was also reflected from the modifications (very few) he has made in his cognitive map after the discussion. For Rose_Jasmin discussion seems to be very useful. He gained a lot by viewing others cognitive maps as well as by participating in the discussion. He was well motivated. He always tried to respond to the queries made by other participants and clarify his own doubts. He has made structural change in his modified cognitive map as per new knowledge gained. For Rajni, the discussion was interesting and he found it as an opportunity to share his ideas about the particular topic with other members. He not only read and understood the content but also evaluated it. He was involved in critical thinking during the discussion. As he was having expertise on the given topic, therefore, he did not feel the need for modification of his cognitive map. This could be also because he was over confident about his understanding of the topic and also did not gain any new knowledge by interacting with the other participants. Rajni' s cognitive map is as follows:



7 Conclusion

In an attempt to answer our research questions, we conclude that learning outcome on the average is better if we consider a heterogeneous group as compared to a homogeneous group. Learning outcome of homogeneous collaborative learning groups has been discussed in another research paper [10]. But then the motivation for learning is equally important for positive outcome. Other skills required such as giving proper attention to the comments of other group members, clarifying any doubts by asking group members or the facilitator and fully utilizing the time available for online discussion by keeping focused attention only on the cognitive maps.

In future we plan to develop a tool for evaluation of cognitive maps and conduct experiments towards the effectiveness of construction of cognitive maps by a collaborating group of learners.

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Impacts of Unintellect Factors on the Design of CAI Courseware

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It is no longer adequate to regard intellect factors as the sole determinant in designing CAI (Computer-Assisted Instruction) courseware, a product obtained when we use computers to assist instruction. Efforts only on improving intelligence can gain little. Here we propose that unintellect factors are necessary and fundamental mechanisms for a successful, effective courseware. In fact, many designers have had some knowledge of the effects unintellect factors have on learning and have applied them in making courseware, but it has not been put forward as a formal subject. In this paper, we will discuss the role unintellect factors play in learning activities and the influence unintellect factors have on intellect factors from five aspects of a person: motivation, interest, emotion, will and character (they make up the core of unintellect factors), then give some constructive suggestions on our courseware development so as to make the products more efficient and more applicable. Moreover we consider unintellect factors very valuable criterions in evaluating a courseware.

Keywords: **unintellect factors, CAI**

1 Introduction of unintellect factors

We can divide human's psychological activities into two kinds: one is of reflection to the world, including notice, perception, recollection, ideation and imagination, etc; they directly participate in the operation of the cognitive activities of the world. The other is of attitude to the world, including motivation, interest, emotion, will and character, etc; they don't directly participate in the operation, but work as motivator and modulator, etc. The former we call intellect factors, the latter unintellect factors. Wechsler(1974) described unintellect factors as follows: (1) The effects of unintellect factors can be found in all range of intellect levels from the simple level to the complex level; (2) Unintellect factors are necessery elements in intellect activities; (3) Though unintellect factors can not take place of the primary capabilities of intellect factors, they can affect their functions in learning.

2 Unintellect factors and learning activities

Unintellect factors and intellect factors are inter-confined and inter-promoted to each other. Influences of unintellect factors on intellect factors are as follows:

- Unintellect factors confine the development of intellect factors.
- Unintellect factors affect the presentation of intellect factors.
- Unintellect factors can make up for some weakness of intelligence.

If we take the whole learning activities as a system, two subsystems constitute this system and cooperate with each other. One is made up of intellect factors, which has executing and operating function and is in charge of perception, understanding, consolidation and application. The other is made up of unintellect factors, modulating the motive. It doesn't participate in intelligence activities, but can elicit, direct, inspire and enhance intelligence activities. Hence, if excluding the great effects of unintellect factors in learning process, these learning activities can not be comprehensive and efficient.

3 Effects of unintellect factors on the design of CAI courseware

3.1 Maintenance of motivation

Motivation is a kind of inner power, which is caused by need stimulation, and which can directly impel a person to objectives. Constructionism requires students to be masters of information processing and positive constructors of meaningful knowledge, instead of passive receivers of external stimulation and indoctrinated objects of knowledge. So it brings forward higher requests to motivation needed in positive learning when there are no constraints and supervision from teachers, especially in some coursewares which allow students self-control study. This kind of courseware gives students more self-determination and freedom on study. Meanwhile it requires courseware to be good enough to maintain even reinforce the motivation of learning.

3.1.1 Give prominence to the content and make the whole structure reasonable

Students' spontaneous learning always comes with problems. If the problem won't get solved after study and students will even be made more confused by unreasonable arrangements, it will greatly set back the initiative of students, even damage the motivation of students.

3.1.2 Utilize the impact of expectation

All students want to get positive expectation form others in view of psychology. For example, teachers continuously let students know the expectation for them. Thus they can always inspire students' unexpected learning motivation. With the development of CAI technology, the role computers play in instruction have changed form simple tools to tutors and partners, which enhances emotion communication between computers and learners in a sense. So we believe we are able to realize these "expectation" in the design of CAI courseware.

3.1.3 Consolidate the sense of achievement

We can discover that if students are able to see their continuous progress with their own eyes, even the progress is not great, but it is going on, then their motivation can become firmer. So in designing CAI courseware, we should deal well with the phase. Generally speaking, a 20% rise form the current level can be set as the best aim. And we can combine the short-range aim and the far-range aim, and let students feel that they are coming nearer to the appointed objective.

3.1.4 Guide students to positive attribution

After the learning, it is not enough only to show the achievements on the screen. We must guide students attribute results to positive factors. Success can make students work harder than ever, and it is more important to help students to find out the reasons of their failure. We should make students form a idea that their achievements are due to their effort, let them feel that their effort is worthwhile and experience the sense of success.

3.2 Inspire interest

Interest is a kind of mind tendency, which makes people study the world positively and voluntarily, and in a sense is a virtue of curiousness. Whether a courseware is a success or a failure is due to the degree it attracts learners. At the beginning, it must be able to draw learners' attentions, elicit learner's curiosity and make them willing to study. This is where the shoe pinches. If it fails at this step, then we can say in some sense that it fails downright. Next, it must keep learners' attention and interest during the learning process, which is also the key difficulty of the design. We must gradually go deeper into the subject, in terms of the content and the form, and offer stronger and stronger stimulation to learners, which can make them keep studying consciously or unconsciously. An excellent courseware is able to make people feel that they are suddenly enlightened but can't get its full meaning.

3.2.1 Make the best of visual and vivid representations of multi-media

We can make a courseware visual and vivid by elaborately selecting and arranging its text, picture, movie, audio and video. Thus learners can have a sense of intimacy and interest to the courseware. This kind of sense will not only work at the beginning but also keep all through the learning by intensively stimulating sense organs. As to the primary school students, we should give further consideration of their interests in the design of courseware, for they are unable to learn by themselves and mostly affected by environmental conditions because of their physical limitation. Of course, the effect of interest can be less and less as they grow elder. But an excellent courseware should use different types of media according to the characteristics of different ages of learners and the requirements of the assigned task.

3.2.2 encourage explorative behaviors

Discovery-learning CAI courseware has adopted the idea of encouraging the learners' explorative behaviors in some degree. Curiosity is one of the sources of interests. The eager to conquer the unknown and to find out the truth stimulate the learners to keep unexhausted interest in the problems. Attention should be paid to the following aspects when in practices:

- Reasonably arrange problem contexts and suspicion.
- Provide sufficient preparations for various emergencies and a perfect helping system.
- Feed back in time, encourage at suitable time and consolidate positively.

3.2.3 transfer interests

There are two types of interest-transference. One is from study-unrelated interests to study-related interests needed, the other is from direct interests to indirect interests. As to the former, we can take the study-unrelated interests as the inducements of the study-related interests in the design of courseware. For example, we can provide a prize(games or cards) relative to the instruction(e.g time or number). Maybe the interests on the prize at the beginning can transfer to study-related interests needed when learners begin to notice their progress. As to the latter, we can combine the direct interests with indirect interests. A good example is instructive game. Games have a kind of charm to inspire players' continuous strong interests. If we integrate tasks and games into one, then studying is playing, playing is studying, and direct interests on games can naturally transfer to indirect interests on study. The learners do not study for the learning results, but for the fun in studying. Of course, a good form of game which can represent the instructive materials is the key point.

3.3 Modulate emotion

Emotion is an experience of attitude that people hold for the world. Good emotion has positive effects and bad emotion has negative ones. CAI has once been said to weaken communications between teachers and students, students and students, enlarge psychological distance between them, and make social communication replaced by interaction. However with rapid development of media technology and enormous progress of communication technology, we are able to break through the limit of invisible "heart" distance, and make CAI courseware emotional. It can act as your tutor, giving you instruction and help; it can act as your partner, discussing and competing with you. So we are utterly able to create a friendly and comfortable learning atmosphere.

3.3.1 Make learning a pleasant activity

We can design from two aspects to make learning a pleasant activity. First, interface pleasing to both eyes and minds can be an artistic creation. Then what kind of framework of CAI courseware can realize optimization? For example, when to provide help is best, how to present the help and to what degree etc., all need theoretical instruction of psychology and pedagogy. We must control the degree, because only "to the point" can make people feel comfortable and pleasant.

3.3.2 Inspire sense of competition

Competition is a very common method. But there are a few rules we must obey when designing competitions:

- Rules must be brief and clear, and requirements must be concrete and reasonable.
- Spans between two difficult levels should not be too large.
- Feedback should be given immediately, and evaluation mostly positive ones.

- Forms of competition should be lively and various.

3.4 Consolidate will

Will is a kind of psychological process that people naturally adjust their behaviors to overcome difficulties ,thus to realize appointed objectives. The effects that will has on study largely depend on a learner himself, but we should not ignore the influence of environment. Despite we can make special CAI courseware for will training, we can also add some extra details in ordinary CAI courseware to create conditions for the reinforcement of learners' will. These extra details have no direct relations to the subject, but their beings can generate great effects. For example, in a difficulty-span-step exercise, if learners have done well consistently, we can think of designing the next step span larger to make the learners act with great care even under smooth circumstance. But if learners have dealt with a puzzle for a long time without a single breakthrough and is going to give it up, we can lay out their past achievements and encourage them to stick to it, or we can reduce the difficulty of the problems to let them re-pick up their confidence.

3.5 Character difference

Character is integration of stable attitudes to reality and corresponding psychological traits of temporary behaviors. Different characters can directly affect one's initiative of learning, one's range and degree of learning activities, and one's attitudes toward difficulties during learning. A great advantage of CAI courseware is that it can provide individual learning. As for this type of CAI courseware's design, we can put into practice from two steps. First, we can realize single-style. This kind of courseware can offer different styles or strategies of learning, and current intellectualized individual learning system does better on this, but it may lead to blindness of selecting. Then, it is integrative-style. This kind of courseware has a testing system, and can provide different versions corresponding to learning styles and learning strategies according to the results of the test. Furthermore, we can take dynamic variability of learners' learning styles and learning strategies into consideration, and provide a tracking testing system.

4 Conclusion

Here, we suggest a few important rules based on our developing practice:

- Rule of interest. Take learners' interests as cut-in point, and keep them all through the courseware.
- Rule of self-master. Arouse learners to be the principal part of learning, and make the best of their enthusiasm for study.
- Rule of development. Arrange structures flexibly and adaptively, allowing a range of change.
- Rule of evaluation. Provide appropriate evaluation in time, which should mostly be a positive one.
- Rule of advantage. Find out learners' advantages, and mobilize their learning energy and confidence.
- Rule of emotion. Create a friendly learning environment, shorten the "heart" distance between learners and computers.
- Rule of elicitation. Arrange problem contexts, inspiring learners to discover and solve problems.

In fact, besides courseware developments, it is valuable to courseware evaluation to attach importance to unintellect factors, because the factors we consider in designing also can be criterions in evaluating. Though more and more CAI coursewares begin to utilize the effects of unintellect factors in learning, this subject still need to be given further research and study. So there still has a lot of work for us to do in the future.

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Towards a Meta-Knowledge Agent: Creating the context for thoughtful instructional systems

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This paper describes a creative approach to electronic courseware authoring. Many online learning systems adopt a generic framework in which cognitive modelling is difficult to achieve. A new CBT package called Cogniware is proposed to bridge this gap by providing a novice-learner with a dynamic instructional device designed to deliver an inclusive learning context. Learners are given the opportunity by this intelligent courseware to identify their cognitive style before embarking on the instructional material. Cogniware will use research findings on the interactive effect of cognitive style and instructional format on the acquisition of complex abstract programming concepts, involving spatial relations and logical reasoning [10], to direct the novice-learner to the instructional format that will best suit their cognitive style. Cogniware will be of interest to educators, cognitive psychologists, communications engineers and computer scientists specialising in computer-human interactions.

Keywords: **Creative learning, educational agent, instructional design, interactive learning environments**

1 Introduction

Reliable mechanisms for courseware design, which provide beneficial flow-ons from research for the training and development sectors [10] are now available. Picking out the important instructional variables (learner's spatial ability, and method of delivery) for some types of instructional outcomes, progresses our ability to provide instructional environments for a broader range of novice-learners. These advancements give the learner a choice of information-transfer-agent, instructional format and instructional event conditions. Too often novice-learners are left to stumble their way through instructional material. We now have the means to deliver customised learning environments. Generic instructional formats often provide too much information, or too little. The meta-knowledge relating to an individual's likely perception of instructional strategies brings our courseware construction into the realm of being truly thoughtful instructional systems' development. In the past, there has been a traditional view that learners adopt a generic approach to make the learning of new abstract concepts meaningful. For instance, the intellectual skill associated with absorbing concepts should be included with the verbal information conveyed during instruction [20]. Cognitive processes involved in learning concepts, are generalization and discrimination [11]. For that reason, individuals generalise from a particular response to learning, to their overall learning experience. Learners look for common attributes that new concepts share with previously encountered ones [11]. However, while still assuming a generic learner cognitive profile, there is now some evidence relating to how an individual's initial mental construct might take the form of a graphical image [5]. That image could serve as a device for mental recognition if the actual object has been seen earlier. Furthermore, mental constructs include the perceptible and non-perceptible attributes of the concept and the cultural meaning given to the name of that concept.

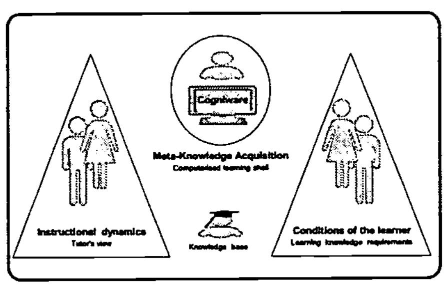
However, there are few examples of research that make a connection between learning abstract computer-programming concepts and graphical-representation as an instructional strategy (see [8]; [9] & [10]. A colour coding process to trace programming logic flow has been devised by Neufeld, Kusalik & Dobrohoczki [13]; and an interactive system, which traces the hidden activities of a computer-programming interpreter has been developed by Smith [18]. Courseware authoring involves the instructional designer in a complex pedagogical process. First, there must be some understanding of how learners deal with the learning content. Next, is the recognition of the interactive effect of an individual's knowledge processing and cognitive style. Finally, the designer needs to be aware of how the dynamics of the meta-knowledge processing (see Figure:1) impact on intelligent tutoring tools.

2 Dynamics of authoring an intelligent tutoring tool

The McKay [10] research has clearly identified the complexity of the meta-knowledge environment, and has outlined prospects for a customised learning shell. Progress is thus possible in linking research outcomes to actual learning contexts. The advent of computerized courseware dictates a need for innovative instructional stratcgies to articulate the visual (pictorial) approach to instruction. However, as this work has shown: not all individuals will cope effectively with a *graphical environment*

However, the observed interactive effect of the cognitive style construct [16] and instructional strategy, may be unique to the acquisition of programming concepts. Therefore, researchers/trainers will need to run an extensive pilot study programme to identify the interactive effects within their specific learning domain. In addition, the instructional material does not need to be limited to a textual/graphical comparison, but could be applied to any two or more instructional treatments of any kind. For instance, a structured versus exploratory strategy. Consequently, a special effort is required to reduce the measurable tension between the instructional mechanism (or dynamics of the tutor's view of the topic) and the actual instructional outcomes (or dynamics of the novice-learner's requirement for specific types of knowledge context). Figure:1 shows the interplay between learning and instruction.

Figure 1: Learning Process Dynamics



The Sternberg [19] approach was to concentrate on the basic information processes in analogical reasoning; while Dreyfus & Dreyfus [2] described stages of skill acquisition as five steps from novice to an expert: novice, advanced beginner, competence, proficiency, and expertise. Be that as it may, it was the sequencing of instruction that reflected the beneficial nature of meaningfulness to the act of learning [7]. Therefore, careful consideration needs to be given to the logical sequencing of instructional events to ensure participants are able to progress through the Dreyfus & Dreyfus skill acquisition steps. Intelligent tutoring systems seek to emulate the learning process, providing a novice-learner with a free fall approach to the pedagogy, or a feeling of being lost in hyperspace [4]. Many of the novice's failed attempts to construct the required domain knowledge are alleviated, when the courseware provides advance notification of the instructional content to promote the intended pedagogic framework. Thus the connection can be made between an individual's prior domain knowledge and their internal representation (Figure:1). This instructional device is called an advance organizer. It occasionally makes learning meaningful by relating new knowledge in a parallel fashion, to what is alrcady known outside the content area [15].

3 Taking a multi-sensory approach

Multi-sensory instruction can improve a student's capacity to learn effectively [1]. This instructional approach maximises the skills brought to the learning task, while minimising the experiences where their ineptitudes are emphasised. Nevertheless, this learning process is often overlooked in the literature, in terms of making new knowledge meaningful by relating to sensory events [17], or to actions already stored in a learner's experiential database (memory). This experiential (human) database is called a sensori-motor database [6]. Accessing this human database is probably the most important method we have for making new knowledge meaningful, during the early years of cognitive development [15]. An instructional strategy can tap into the power of an individual's sensori-motor database, with an innovative textual metaphor, for explaining conditional logic flow to a novice programmer. This textual metaphor describes a common event to support a reflective approach to acquiring the programming concept of conditional logic patterns, thereby encouraging a novice-learner to access their sensori-motor database, to implement a new concept. Experiential leverage for developing the procedural knowledge is gained through providing hands-on experience with example problems. There is a relationship between cognitive level and mental energy consumption in different learning activities [14]. Reading and listening are mentally and physically exhausting with dull and poorly designed material, thereby losing the reader's interest. Furthermore, there is another relationship between cognitive level and suggestive impact, for different kinds of instructional representations [9]. Therefore, designers should be conscious of this and strive to design their learning materials (text and pictures) in the most attractive, and relevant manner possible, so that novice learners are encouraged to process the content (message) on the highest possible cognitive level.

4 Cogniware

Following the premise that a multi-sensori approach is beneficial to learning. Cogniware has been developed using the Electronic Trainer authoring tool from Mindware Creative Inc. At present it consists of a front end module to determine the learner's cognitive style (the CSA [16]), and a choice of instruction method for the acquisition of programming concepts. Cogniware is multi-sensori in the sense that the instructional strategies on offer provide the learning material in a range of alternative instructional conditions. Figure:2 depicts a typical Cogniware screen interface with three instructional formats or separate viewing areas: graphical, textual, and voice. In addition there are cueing mechanisms for guided exploration, such as: directional icons, a learning module name tag, and an advance organizer screen.

Figure 2: Towards a Meta-Knowledge Agent

Cogniware provides the background material on different modes of learning in a textual description interface, while at the same time a voice description can be heard.

4.1 Choice of instructional format

Currently, Cogniware has three types of instructional format available: graphical, textual, and voice (see Figure:2), thereby providing the learner with the format which best suits their cognitive style. However, Cogniware is also flexible enough such that a learner can over-ride the default for the chosen format. Programming metaphors are used as expository instructional strategies. In so doing, they articulate the critical attributes of the concept-to-be-learned [12].

4.1.1 Textual

There are a number of ways in which we can aid the comprehension of the written word. To overcome one of the central difficulties associated with text processing, Cogniware provides the reader with the best possible means to select important information from the text [3]. Hotwords are included as pedagogical cues to navigate a novice-learner through a new concept. Text should not be considered as a flat structure, where all ideas are expressed with equal importance. The Cogniware text is therefore a highly structured communication tool, in which ideas are expressed hierarchically, where certain parts of the message can receive more attention than others. As a consequence, particular display techniques enable the reader to focus on the full context of the message by selecting the important issues without being overwhelmed by poorly structured text.

4.1.2 Graphical

Graphical metaphors used by Cogniware were chosen for their recognisable and distinguishing (or salient) features, to depict each programming concept to be learned. These visual metaphors serve to elicit prior experiential knowledge, enabling the learner to recognise the distinguishing features of the new concept, and to interpret the instructional context without specific prior learning.

4.1.3 Voice

The learner can view the video interface to hear a verbal description of the programming metaphors. Advice and reassurance is also provided to ensure maximum coverage of the multi-sensori platform. Voice directions for dealing with the CBT navigation are designed to reduce the cognitive effort required in dealing with the complexities of multi-media instruction. Reminders can be seen as a useful technique to keep the novice-learner on track. It is intended that demonstration video clips will be included in future releases of Cogniware to extend the multi-sensori capability.

5 Conclusions

Cogniware represents a creative approach to electronic courseware authoring. The sound instructional design foundation upon which this courseware is built, draws on the research conducted by Merrill's ID_2 team at Utah State University, USA, and recent research by McKay & Garner [9]. The latter research provided the experimental findings to link the important work on the Cognitive Styles Construct carried out at Birmingham University, UK , by Riding [16] with the effectiveness of various instructional formats. Cogniware was authored using The Electronic Trainer providing the ideal knowledge based framework for authoring electronic courseware. Online learning systems adopting a generic framework reveal that cognitive modelling is difficult to achieve. It is proposed that Cogniware bridges this gap by providing a novice-learner with a dynamic instructional device designed to deliver an inclusive rather than exclusive learning context. At the nexus of this CBT is the ability afforded to learners to identify their cognitive style before engaging with the multi-sensori instructional devices, allowing selection of an optimal instructional format. Cogniware will be of interest to educators, cognitive psychologists, communications engineers and computer scientists specialising in computer-human interactions. Researchers can now provide a better understanding of the interactive effects of the cognitive style construct and instructional format on the acquisition of abstract concepts, involving spatial relations and logical reasoning [10].

Educational researchers are reminded to work towards ensuring their instruction works for people rather than ensuring their instruction works for the technology.

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Microgenetic Analysis of Conceptual Change in Learning Basic Mechanics

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Microgenetic approach to understanding the process of cognitive development entails repeatedly assessing participants' performance on a conceptual domain undertaking rapid change. In the present study, we adopted the microgenetic method to examine the conceptual change process in learning elementary Newtonian mechanics. Twelve junior-high school students with comparable competency in mechanics were assigned to two groups, and their understanding of concepts in elementary mechanics were assessed in four occasions by interacting with a computerized test-bank software. Participants in the group-test condition were assessed in a group setting. Participants in the individual-test condition were additionally asked to provide explanations for their answers to each test item. The results showed that while participants benefited from being repeatedly tested and showing a increasingly higher level of sophistication in their understanding for most of the conceptual domains tested, it doesn't matter whether or not they also offered explanations to their own answers. More importantly, the differences in developmental course across conceptual domains and the variability of developmental course within conceptual domains together lend support to the theoretical assumptions of the microgenetic approach.

Keywords: **conceptual change, microgenetic analysis, computer-assisted testing, basic mechanics**

1 Introduction

There is little doubt that one of the major challenges in understanding cognitive development is to have an adequate account for the process of conceptual change. Over the last few decades, research in cognitive development has produced a number of distinctive approaches to understanding the process of conceptual change. Among them, Piaget's stage theory was most prominent and has influenced virtually all trades of research in cognitive development. However, numerous theorists have seriously challenged Piagetian theories over the past decade [1, 2, 3, 4, 6]. One of the main criticisms these theorists raise against the Piaget's theory was its lack of precise specification of the mechanisms underlying conceptual change. Most recently, Siegler and his colleagues have proposed a new approach, the microgenetic analysis, to unravel the process of conceptual change [5, 6, 7]. In essence, the microgenetic method entails a dense sampling of observations so that a concept under rapid change and development can be effectively described and analyzed. In particular, [5] has suggested five dimensions or aspects to reveal the change process, namely path, rate, breadth, variability and sources of change [6]. In the present study, we adopted the microgenetic approach to examine junior-high school students' understanding of basic mechanics. Their understandings were assessed either in a group setting or individually. In the former the participants were merely required to interact with a computerized test-bank software. In the latter, the participants were required to provide explanations to their answers in addition to interacting with the test-bank software. The main reason to have such a manipulation was because there is evidence indicating that self-explanations could promote learning, especially in the conceptual domain [5, 9].

2 Method

Participants. In order to find two groups of junior-high school students with comparable competency in elementary mechanics, we first administered a paper-and-pencil conceptual test of mechanics to 280 junior-high school students from 6 classes of a private high school in the Chiayi County in Taiwan. We then selected 12 among the class of students that had a mean score close to the average performance of the entire sample. Those students had scores that were right at the level of class average. They were randomly assigned to two groups that were tested either individually or in a group setting.

Materials and apparatus. In order to effectively assess participants' conceptual development in their understanding of basic mechanics, we first built a computerized test-bank software. The test bank contained multiple-choice questions with multimedia presentation (see Figure 1 for illustration) and covered nine different units of basic mechanics, namely, (a) displacement and its magnitude, (b) average and instant velocity, (c) 2-D coordinate systems, (d) X-T graphs, (e) V-T graphs, (f) translation between X-T and V-T graphs, (g) motion equations, (h) Hook's law, (i) static equilibrium, and (j) vectors (differentiation and integration). For each unit, we first established the levels of conceptual sophistication that seemed to be appropriate for that unit. The levels represent a progression from rudimentary understanding to elaborate mastery of a given conceptual domain. Due to the variation in conceptual complexity of each unit, the levels of sophistication varied from 3 to 5, reflecting the relative difficulty and complexity among items constructed for each level. There were 10 streams of parallel items constructed for each conceptual unit; as a result the test items for each unit varied from 30 to 50 items. The items were parallel in the sense that only the protagonists and/or numerical quantities were altered between items at the same level of sophistication. Although we constructed a complete set of test bank, only units of *a* (displacement), *c* (2-D coordinate system), *d* (X-T graphs), *h* (Hook's law), and *i* (static equilibrium) were administered to the participants due to the constraints of available time and the background knowledge covered in their regular courses on mechanics.

Figure 1. An example of computerized test item for assessing conceptual understanding of basic mechanics.

Procedure. The participants were tested in two groups, six in each group. For the group-test participants, they were assessed in a group setting (in the school's computer room), although their interactions with the test-bank software were essentially independent of one another. For the individual-test participants, they each interacted with the software separately via a notebook. Their interactions with the test-bank software, including the answers they gave for each item and the explanations they offered for their answers, were videotaped. The test-bank software was also equipped with a database for recording various aspects of participants' interactions with it, including the item number, the level of sophistication for a given item, the answer, the accuracy of the answer, the reversal index, and exit type, among others.

Participants' understanding of the five units in elementary mechanics was each assessed four times for both groups, over a period of about 4 months. The first two assessments were conducted toward the end of the spring semester and the second two assessments were conducted at the beginning of the fall semester, interrupted by the summer break. For each assessment, we adopted an adaptive testing principle by using the staircase method typically used in psychophysical research [8] for assessing the threshold. The staircase method we used entailed raising one level of difficulty (sophistication) after correctly answering two consecutive items at the same level, and lowering the level of difficulty whenever an incorrect answer was encountered. According to Levitt (1971), this procedure would yield a (conceptual) threshold value of about .71, a value that is normally used in psychophysical research. When participants answered incorrectly on an item, they were subsequently given items that were at a lower level. If they answered correctly on items that were presumably easier, they would be given items at a higher level of difficulty. At this juncture, a reversal point would be registered as the level of difficulty for items that were preceded *and* followed by items at a higher level of difficulty. A second type of reversal point has the opposite property, namely items that were preceded and followed by items that were at a lower level of difficulty. For each round of assessment we collected 5 reversal points before allowing the participants to exit from the test. The mean of the five reversal points was then used to define the level of conceptual understanding for the participant.

We also designed alternative routes for exiting the test bank software. Some of the units were relatively easy such that participants were able to correct throughout all levels of difficulty. If that happened, we would allow them to exit when they answered correctly three items in a row at the highest level of difficulty. In contrast, some units were relatively difficult, at least in the first round of assessment, such that participants were unable to advance themselves from the first to second level. We also allowed the participant to exit if they were incorrectly on three items consecutively at the first level.

3 Results

We first computed, for each of the five units examined, the mean value of conceptual threshold for each participant for each of the four rounds of assessment. These mean values of threshold were then submitted to a 2 (group) x 4 (round) mixed analysis of variance (ANOVA) for each unit separately. As can be seen in Figure 3, the differences between the two groups of participants did not reach significance level for four of the five units, namely, displacement, coordinate system, Hook's law, and static equilibrium, F's < 1 or p's > .15. The difference between the two groups approaches significant for the unit of X-T graphs, $F(1, 9) = 4.90$, $p = .054$, indicating that on average the individually tested participants ($M = 2.68$) performed better than their group-tested participants ($M = 2.05$) The main effect of round of assessment was highly reliable for two of the five units, $F(3, 27) = 6.38$, $p = .002$, for displacement, and $F(3, 27) = 5.49$, $p = .004$ for X-T graphs. It was marginally significant for the unit of Hook's law, $F(3, 27) = 2.84$, $p = .057$, but was unreliable for units of 2-D coordinate system and static equilibrium, F's < 1.

Because the participants were tested four rounds in succession, the data allow us to perform trend analyses in addition to the omnibus ANOVA. The results of trend analysis for the three units that participants appeared to undertake rapid change reveal the following findings: For *displacement* unit, both the linear trend and the cubic trend were reliable, $F(1, 9) = 8.51$, $p < .02$, and $F(1, 9) = 12.45$, $p < .01$, respectively. Likewise, for *X-T graphs* unit, both the linear and cubic trends were reliable, $F(1, 9) = 5.79$, $p < .05$, and $F(1, 9) = 7.25$, $p < .03$, respectively. Finally, for *Hook's law* unit, only the cubic trend was reliable, $F(1, 9) = 10.68$, $p = .01$, but the linear trend was not, $F(1, 9) = 2.25$, $p > .16$.

4 Discussion and Conclusion

The findings of the present study indicate that three of the elementary concepts in mechanics we examined—*displacement and its magnitude, X-T graphs,* and *Hook's law*--were under rapid change such that with four rounds of assessment, spanning a period of 4 moths, we had witnessed nontrivial change over time. It is interesting to note that the pattern of conceptual change for both displacement and X-T graphs units not only exhibited a pattern of monotonic increase in level of sophistication, and thus yield reliable linear trends, but also exhibited reliable cubic pattern, indicating that the conceptual understanding was not as stable as a stage theory would have predicted. That is, almost all participants, regardless of the setting in which they were tested, exhibited the pattern that while they had a better performance at the second round of assessment, their performance dropped on the third round of assessment before they advanced themselves again at the four round (see Figure 2). Those who have criticized the stage theories such as Piaget's have noted such a pattern. According to stage theories, participants should at least remain at the same stage of development once they reach at a given stage. It is in this sense that the microgenetic approach can offer a picture that perhaps is closer to the reality of developmental course. There were also units, namely, the *2-D coordinate system* and *static equilibrium*, to which our participants demonstrated their understanding and mastery early on such that no substantial change was observed over the period of assessment. These differences among the units once again demonstrates the strength of microgenetic method in that not all conceptual domains would undertake a uniform course of development. Finally we were somewhat surprised to find that self-explanations did not exert reliable effects on our participants' performance. One possible reason may have to do with the fact that the test items we constructed were really geared toward participants' basic conceptual understanding, In so doing we may have greatly reduced the complexity of those conceptual domains such that whether or not self-explanations were required was ineffective in promoting conceptual change. [9]

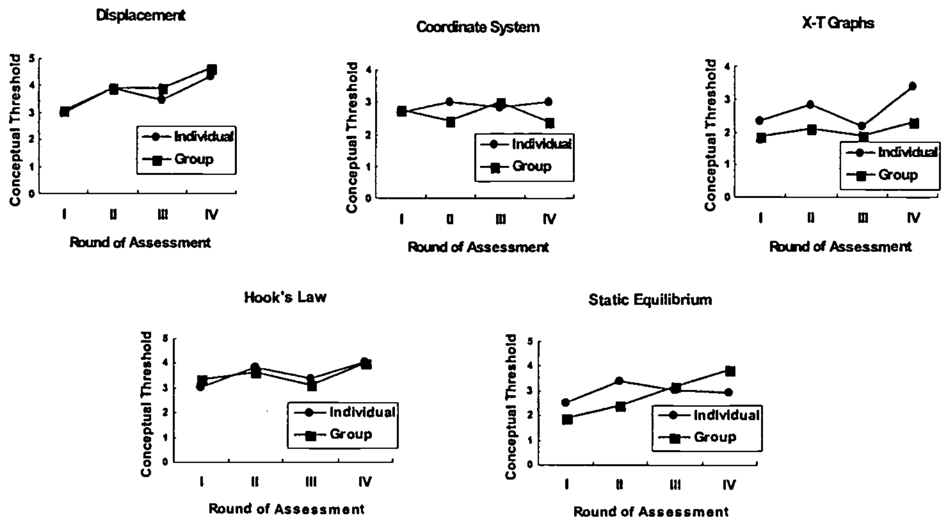

Figure 2. The conceptual threshold value for each unit as a function of round of assessment and test setting (individual vs. group).

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Scientific revolutions and conceptual change in students: Results of a microgenetic process study

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A microgenetic process study of dyad learning was conducted with the objective of further understanding conceptual change as students learn. This paper describes the knowledge negotiation, co-construction, and problem-solving efforts between two student volunteers, both aged 15, in a computer-mediated-communication (CMC) environment. We illustrate protocols of the students' problem-solving processes, showing how the students manifested, expressed, defended, abandoned, conjectured, and eventually transformed their (mis)conceptions on various aspects of velocities and distances. In doing so, we address important questions raised about students, their concepts and (lack of) theories, and the types of conceptual change that take place as students learn. This paper provides empirical evidence to show that as long as students do not think in theoretical terms, conceptual change in students will be very different from scientific revolutions. It not only agrees with the theoretical shift to viewing *learning* as *conceptual change*; it also lends empirical evidence in support of this view.

Keywords: **Cognition and Conceptual Change, Collaborative Learning, and Knowledge Construction and Navigation**

1 Introduction

The study and understanding of conceptual change is a field that is significant to the research community [10]. An example of macro-level conceptual change is the paradigm shift [8] from the phlogiston theory to the oxygen theory (commonly dubbed the chemical revolution). There have been numerous attempts to compare and contrast between such scientific revolutions and conceptual change in children and students. For example, Carey [2] contends that the development of the concept *living thing* in a child is analogous to scientific revolution because her study shows that between the ages of 4 to 10, children undergo a cognitive restructuring of their *living thing* concept; this restructuring is tantamount to theory change (from an animist theory to a set of biological theories). On the other hand, Harris [5] argues that "children do not think in theoretical terms, but on the basis of working models or concrete paradigms that serve as a basis for predictions and explanation" (p.303). Given these two opposing viewpoints, it is natural for Thagard [21] to state:

> The questions remain: do children have theories, does conceptual change occur by replacement, and is theory replacement the result of considerations of explanatory coherence? An affirmative answer to each question is a precondition of an affirmative answer to the succeeding one. (p.256)

Before discussing whether conceptual change in students is as revolutionary as scientific revolution, we should be reminded that scientific revolution involves a paradigm shift from one theory (or theories) to another competing theory (or theories). At the risk of oversimplification, we define a theory to be a set of *explicit* and *well-coordinated* principles that yield *predictions* based on their *explanatory mechanisms*. Since all "conceptual structures provide some fodder for explanation", "the distinction between theory-like structures and other types of cognitive structures is one of degree" [2, p.201]; theories embody deep explanatory notions.

Given the above, if students do not possess theories, not only is conceptual change in students fundamentally different from scientific revolution, but we must also offer negative answers to Thagard's questions.

2 Context of Study

This study describes how two student volunteers, Tim and Ming (both aged 15), engaged in meaningful knowledge negotiation and co-construction in a manner that allowed their conceptions and thought processes to be made overt for our analysis. Tim and Ming are schoolmates (but not classmates) in an academically average neighborhood secondary school. Both students have learnt physics in school for one year prior to this study and hence, are familiar with the terms velocity, acceleration, time, and distance. Prior to this, both students have not worked academically with each other.

Tim and Ming were placed in a large room that was partitioned in the middle. Each student occupied onepartition, and conversed with the other exclusively via a computer-mediated-communication (CMC) environment. The CMC environment consisted of a chatbox and whiteboard facility. The chatbox facility allowed the two students to converse via typed text, while the shared whiteboard allowed pictorial drawings and ideas to be depicted and discussed. Figure 1 shows a snapshot of this CMC environment, implemented via Microsoft NetMeeting™. Besides the standard furniture such as tables, chairs, and a computer, each partition housed two unmanned video cameras. The main data collection method comprised the video recordings of the students' interactions through the CMC environment. In each partition, a video camera was directed at the screen, capturing every interaction sequence performed on the computer, while the other video camera was directed at the student, capturing the student's physical gestures and reactions. To further aid the transcription process, both the shared chatbox and whiteboard were regularly "saved."

The questions that we posed to the students to solve were adaptations of the "Context Rich Problems" formulated by the Department of Physics, University of Minnesota (for more information, see http://www.physics.umn.edu/groups/physed/Research/CRP/crintro.html).

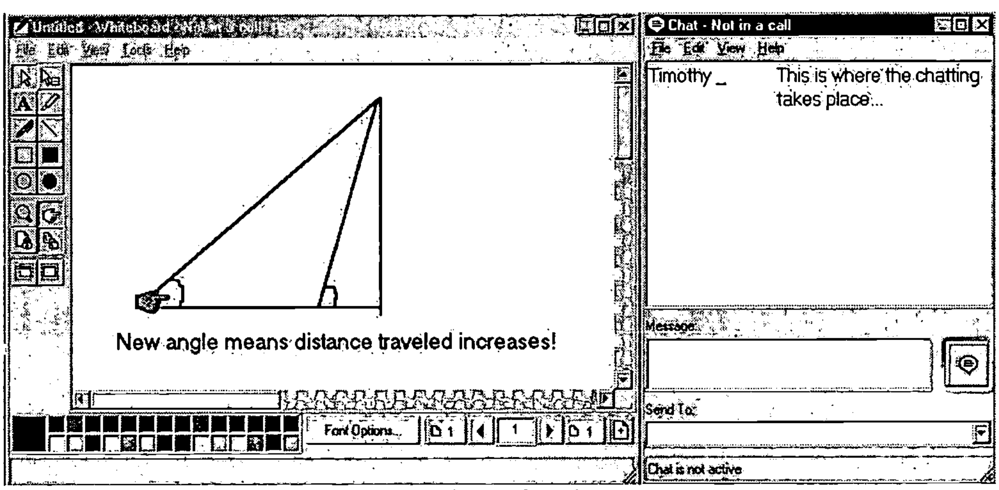


Figure 1: The CMC environment

3 Research Methodology

If we simply engage in endpoints analysis, we would not be able to understand conceptual change [10]. As such, we need to take into account the actual developmental process of conceptual change. A research methodology that focuses on microgenetic (developmental) processes is that of Ethnomethodology [4]. In short, ethnomethodology is interested in interaction sequences and requires that we focus on "participant categories" rather than "third person observer" perspectives [7]. It forces us to ask, "what questions can the data answer" rather than "what data do I need to answer these questions."

Since conversation analysis is the most productive and prolific form of analysis that has been developed with ethnomethodological concerns in mind [1], the protocol data obtained were transcribed into a log format, and then analyzed and annotated in accordance with the practices of conversation analysis (see also [6, 9, 12, 13, 17]). This was a time-consuming process as each tape had to be viewed and reviewed until the gaps in the data were resolved to the fullest extent possible.

4 Study Findings

In the following section, we illustrate portions of Tim and Ming's problem-solving processes through protocols collected in our study. Because this paper only presents portions of the protocols collected, see Soong [19] for full details. The question below details one of the problems attempted by Tim and Ming.

The cycling problem:

You and your physics teacher are cheering your cyclist friends Alex and Bon who are taking part in a straight but uphill bicycle-racing contest. You and your teacher are watching the race from the side-lane just beside the racetrack, 132 meters away from the finish line. It so happened that both cyclists passed by in front of you at exactly the same point in time. Your teacher estimated Alex's velocity to be 12m/s and Bon's velocity to be 11m/s. Given your training sessions with Alex and Bon, you know that from this position, Alex will accelerate at the rate of $0.25m/s^2$, while Bon will accelerate at the rate of $0.4m/s^2$, for the next 10 seconds.

- What is the final velocity of both cyclists at the end of that 10 seconds?
- Who will reach the finish line first?

Comments in square brackets "[ ]" are remarks made by the author regarding the protocol statements. These comments aid understanding of the protocols by relaying contextual information not available to the reader. No attempts were made to correct the students' grammatical and spelling errors. Tim, Ming, and the author are represented by "T", "M", and "A" respectively.

```
4.    M: part a looks tha same as what we did in the last session
```
[The first part of this question looks the same as what they previously attempted]
```
5.    T: yes....
6.    M: can we use that method?
```
T: lets try

Both students drew structural similarity between Part A of this question and a question that they previously attempted. In that previous problem-solving session, T and M had agreed that "(acc. x acc. time) + initial velocity = final velocity". However, the reason they agreed on this formula was because "it's the only method where we could get the ans. so far". It is clear that the students lacked a conceptual understanding of the solution, but nonetheless that did not hinder them from solving the problem.

It is noteworthy that M referred to the problem-solving process as "that method", rather than "that theory" or even "that logic". It is clear that in this instance, the students did not think in theoretical terms. In fact, it was a mechanical application of the "method" that the students "did in the last session".

With this, the students worked collaboratively, using the formula *final velocity = (acceleration x acceleration time) + initial velocity*. They then obtained the (correct) solution that Alex's final velocity was 14.5 m/s while Bon's final velocity was 15 m/s.

```
11.   M: 12+2.5=14.5
12.   T: yes
13.   T: and bon = 11 + 4 = 15
17.   M: agree?
18.   T: yup
```

It was clear to both students that Bon was faster than Alex after the acceleration. However, both the students had the conception that an object with a higher final velocity travels further than one with a lower final velocity. This conception is true in some, but not all cases. This is a well-known misconception, and it has been documented extensively by Piaget [11], among others. In the context of our study, we will refer to this as the "higher final velocity = winner" concept.

```
38.   T: bon is faster after the acc.
39.   M: yes
40.   T: therefore if the speed be constant after the acc., bon would
   complete the race first
41.   T: agreed?
44.   M: agree.
```

Confident that their answer was correct, T checked their answer with the author, only to be informed that their answer was incorrect, since Alex will actually complete the race first. When T related this to M, he was surprised.

```
47.   T: nope.....
48.   T: wrong ans....
49.   M: huh?
```
[M is surprised that their answer was incorrect]

When the author informed the students that their answer was wrong, the students tried again. T stuck to the concept that an object with a higher final velocity will travel further than one with a lower final velocity. Since T was basing his problem-solving attempts on this concept, he thought the only possible reason why Bon did not win the race was that his final velocity was lower than that of Alex's. To allow for this, he hypothesized that both bicycles returned to their initial velocities after the acceleration.

```
53.   T: they will only acc. for that 10 s
54.   T: after that their speeds will return to the same as b4
```

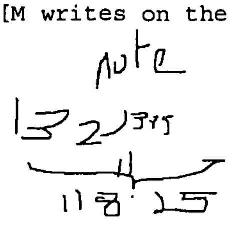
At this point in time, the author informed the students that the bicycles did not decelerate after that 10 seconds. Upon hearing this, both students felt that Bon should win. Their expression was totally consistent with their conception.

```
62.   A to T: They did not decelerate after the 10 seconds.
65.   T: the 2 didn't decelerate
66.   M: then b should win
67.   T: yah........
```

In the episode above, T was trying to reconcile their findings via qualitative analysis of the situation. However, because their source of reasons came from their "higher final velocity = winner" (mis)conception, this yielded no alternative results.

The episode below shows M's attempt to obtain an alternative answer via mathematical formulations. In so doing, M unwittingly put aside the "higher final velocity = winner" concept.

```
84.   [M writes on the whiteboard]
```



```
86.   M: a travelled 118.25 to the checkpt
```
[M was referring to his workings on the whiteboard. See L88, L89 and L92 for an explanation of M's workings]

```
87.   T: y is that so?
```
[T looks at M's drawing on the whiteboard]

```
88.   M: 0.25+(2x0.25)......+(2.5)=13.75
89.   M: the distance travelled during acceleration
```
[13.75m is the (additional) distance covered due to the acceleration]

The protocol above manifests another of M's misconception. M's workings imply that the bicycles gain speed instantaneously rather than incrementally. In short, M's workings imply that Alex's bicycle covered an additional 13.75 meters due to its acceleration of $0.25m/s^2$ for 10 seconds. We observe that this exact same working was also exhibited by M in one of his earlier problem-solving sessions.

90. T: ok.....
91. T: but i still dun get it....
[T does not understand M's workings]
92. M: 132(distance from check pt)-13.75=118.25
[132m - 13.75m = 118.25m]
[M is saying that the initial portion of Alex's velocity covered 118.25m]
93. M: there/s no decceleration,then bon should reach first!

It is likely that, to M, the distance traveled by Bon due to Bon's higher acceleration was greater than Alex. Based on this method, Bon would have traveled 22 meters due to his higher acceleration. Hence, M drew the conclusion that Bon should reach the finish line first, since Bon was "faster". Clearly M's reasoning was flawed.

94. T: how u get 13.75?
95. M: 0.25+(0.25x2)+(0.25x3)+(0.25x4)...... +(0.25x10)=13.75

Upon further probing by T, M provided a fuller explanation of his conceptualization. M's formulation is as follows:

The velocity of Alex due to acceleration during the 1st second is = $0.25m/s^2$ x 1s
= 0.25m/s

Hence Alex, moving at 0.25m/s, travels 0.25m/s x 1s = 0.25 meters during the 1st second.
Likewise, Alex's velocity due to acceleration during the 2nd second is = $0.25m/s^2$ x 2s
= 0.5m/s.

Hence Alex, moving at 0.5m/s, travels 0.5m/s x 1s = 0.5 meters during the 2nd second. The same process was extended until the 10th second. As such, M conceptualizes that the summation of the distances from the 1st to the 10th second indicates the total distance traveled during the 10 seconds. Figure 2 and 3 pictorially illustrate M's conception and the actual acceleration process respectively.

Figure 2: M's Conception

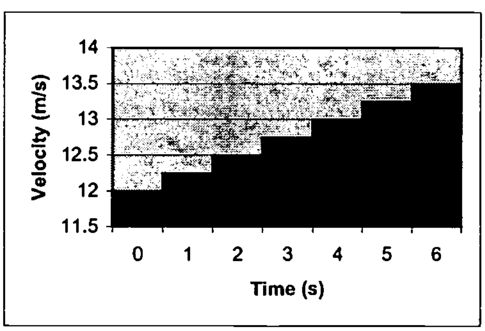
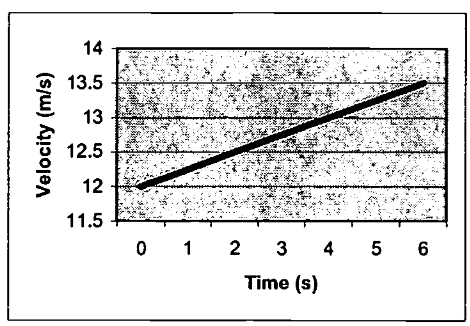


Figure 3: Actual acceleration process



T thought long and hard about M's formulation. After doing the math, he understood and agreed with M's conceptualization. This provides us with evidence that T had this misconception as well.

96. T: [long pause (thinking)]
97. T does the maths
98. T: oic
[This is a short form for "Oh, I see"]

Discussing the problem-solving process by qualitative analysis failed to provide new insights. As such, M started using mathematics as an alternative source of potential explanation. M's workings reveal that he had a misconception that the bicycles gain speed instantaneously rather than incrementally. We also see evidence that T suffered from the same misconception. Despite the use of both approaches, both students were unable to find any reason why Alex should win. Hence, they concluded that Bon would win. With this conclusion, they checked again with the author, only to be told that they were incorrect.

110. M: no.............................
111. T: huh?
[T is surprised that the answer was incorrect]
113. M: that's no the ans..
114. T: i don't get it....
115. M: smae here.....

Faced with this bleak situation, both students, perhaps unwittingly, put aside their "higher final velocity = winner" conception. Evidence of this is shown when, without first thinking it through, M suggested that perhaps both bicycles arrived at the same time.

117. M: maybe they arrive at the same time?
118. M: assume
119. T: it may be possible but wat is the reasoning...?
120. M: thinking.......

Perhaps unknown even to M, he was putting aside the "higher final velocity = winner" concept by suggesting that "maybe they arrive at the same time". This suggestion was made without even an initial reason, and hence this suggests that the students did not think in theoretical terms.

Because the students had put aside the "higher final velocity = winner" conception, they were able to make progress in solving the question.

124. T: acc. = total dist travelled / total time taken
[T makes overt his thought process to M]
125. M: that's speed
[M corrects T]
126. T: aye.... yah hor.....
[Local expression for "Oh yes, you are right"]
127. M: acc=what formULA?
128. T: the gradient of the distance time graph....
[This is actually incorrect; acceleration is the gradient of the velocity-time graph]
129. M: huh?
[M was not expecting this]
130. T: the acc. is the gradient of the distance-time graph
134. M: could u find the time ?
135. A to M: Do you agree that "acc. is the gradient of the distance-time graph"?
136. M: acc.=changes in velocity/time taken
[After pondering over the author's question, M gives an accurate definition for acceleration]

As T searched broadly for answers, he drew upon the formula of acceleration. However, his definition was incorrect. This set M thinking about the actual formula of acceleration and "the time" (L134). M then started to use the formula *time = distance traveled / (velocity+acceletion)* in order to find the time taken for each bicycle to complete the final 132 meters. While M's actual workings were incorrect (there is no such formula), it nonetheless provided the students with an alternative answer suggesting the conclusion that Alex won the race. More importantly, it allowed the students to derive the relation between the time of race completion and the winner of the race.

151. M: a move faster than b.....reach first.......z???????
[M draws the relation between *time of completion of race* and *winner of race*]
156. M: 132/(12+0.25)=132/12.25=10.76
[132 is the distance traveled, 12 is the initial velocity, 0.25 is the acceleration]
157. M: A
158. M: 132/11.4=11.58
[132 is the distance traveled, 11 is the initial velocity, 0.4 is the acceleration]
159. M: B
160. M: i getting a little bit confused
[Perhaps M noticed that the formula he used made no sense]
161. T: oic/......these ans are the time taken for the cylist,....

```
162.  T: therefore, A takes less time and b takes longer..
164.  T: so A will reach first
```

M's workings were incorrect. He had used a formula that had no basis, but nonetheless, T was able to make sense of it and concluded from M's answer that since Alex took less time than Bon, Alex will reach the finish line first. This provided the students with an alternative answer, and they were excited. M immediately asked the author if they were correct.

```
165.  M to A: Correct?
166.  A to M: The answer is correct, but the working is wrong
167.  M: working XXXXXXXXX
```

Upon hearing that the answer was correct, M deduced correctly that because Alex traveled faster initially, Alex was at a point ahead of Bon such that Bon could not overtake him despite Bon's higher acceleration. This provided the students with a reason why, despite his higher acceleration and final velocity, Bon lost to Alex.

```
172.  M: a travelled faster aT FIRST SO HE'S AT A POINT FURTHER THAN
   WHERE B COULD OVER TAKE EVEN THOUGH B ACCELERATE FASTR.
```

The above problem-solving endeavor took about 50 minutes. From here onwards, the students continued their problem-solving efforts. After considerable struggle, they eventually "corrected" their second manifested misconception (the "stepwise velocity increment" conception). They were also able to obtain a correct mathematical process to show Alex completing the race before Bon. The total time taken to solve this question was 130 minutes.

5 Results

The results of our study show that our student volunteers did not think in theoretical terms when attempting to solve the physics (kinematics) problems. Instead, they used a variety of methods such as simulations, conceptions, and even baseless conjectures. While these students certainly have concepts and based their reasons on these concepts, they were loose, unsystematic and highly fragmented. We may be tempted to call these students "naive learners", but further research by the authors reveal that the vast majority of elementary physics students who were studied worked in this fashion.

The students' "higher final velocity = winner" conception stemmed from their prior knowledge, and because their source of reasons came from this conception, they were unable to understand how it could be that Bon, who had the higher final velocity, did not reach the finish line first. Only upon putting aside this concept were they able to appreciate how it could be possible for an object with a higher final velocity to reach the finish line later than an object with a lower final velocity; it was because the slower object was at a point further than where the faster object could overtake. The protocols strongly support constructivist learning theory, which posits, among other things, that new knowledge is built (or constructed) from prior knowledge [15, 16]. Our study not only agrees with the theoretical shift to viewing *learning* as *conceptual change* [21]; it also lends empirical evidence in support of this. It also shows the conceptual change process (and hcnce learning process) to be continuous, but non-cumulative. This particular *feature* is strikingly similar in structure to scientific revolutions.

With respect to Thagard's request to "pin down the kinds of conceptual change that occur as children learn" [21, p.260], the kind of conceptual change that occurred here is that of "adding a new strong rule that plays a frequent role in problem solving and explanation" [21, p.35]. Initially, the students had the conception that an object with a higher final velocity (B) implied that it would travel further than one with a lower final velocity (A). Their problem-solving efforts added a new rule to this concept: B would travel further than A *only if* A is not at a point ahead of B such that B could not overtake A despite B's higher acceleration and higher final velocity.

6 Conclusions

Here in Asia (and in many parts of the world), the current method of teaching and assessing primary, secondary, and pre-tertiary students (aged 7-18), is still very much based on the over a century-old Western pedagogy of teaching boys and girls nothing but *facts* [3]. Such a methodology is efficient for dissemination of information, but this decontextualised-content focus causes students to suffer from a lack of deep conceptual understanding of the domain being taught, and immensely decreases their exposure to expert problem-solving processes and strategies. As such, they do not look at problem solving through a "theoretical lens." Since "advancement in science is a continual dance between the partners of theory and experiment, first one leading, then the other" [14, p. 796], as long as students do not think in theoretical terms, negative answers should be offered to Thagard's opening quote.

Learning environments, computer-based or otherwise, should be designed to play a more *strategic* role with the *objectives* of the educational system as their core focus. Since the objectives of educational systems are rarely to produce unadaptable and inflexible graduates concerned only with egotistical benefits, then the learning environment, as well as the evaluation methodology, should be designed to reflect their intended objectives (also see [18]).

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The Effect of Virtual Reality Learning Transfer with Different Cognitive Style

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The virtual reality has great potential capacity in distance learning. There are three characteristics of virtual reality learning, simulation, interaction, and involvement of multiple users. The purpose of this study is to discuss the effect of virtual reality learning transfer with different cognitive style, and recognize the relationship between cognitive style and relatively different form. Cluster sampling was used in this study. Two schools, Kwan Hwa Junior High school and Youth Junior High school, were selected for sampling. Two classes of each school were recruited. Four research instruments such as "Cognitive Style Profile", "The Need for Cognitive Scale", "Computer Attitude Profile" and "The learning classroom of virtual reality" were used for evaluation. The main finding after analyzing the score statistically are as followed:(1).The cognitive style of students is generally good and above medium level, however, it seems not very good at discrimination skill.(2).The verbal spatial preference skill of students leans toward the spatial learning.(3).The computer attitude of students is good generally and has positive attitude.(4).The social position and owning computer have a remarkable influence on the VR learning transfer; yet sex, learning computer experience and family education mode do not have a distinguished influence on learning.(5).Increasing the opportunity for students to use computers helps VR learning transfer by computers.(6).The VR learning transfer differed by the difference of cognitive need.(7).The number of computer attitude will influence VR learning transfer, that one having positive (computer) attitude is much more efficient than the negative.(8).Discrimination skill and spatial skill will influence the VR learning transfer.(9).The number of different personal factor have a remarkable influence on cognitive style, cognitive need and computer attitude; yet family education mode does not have a distinguished influence on them.(10).The discrimination skill, spatial skill, cognitive need and computer attitude have a remarkable positive correlation with the VR learning transfer.(11).By means of predictive analysis, attitudes in computer, cognitive need and cognitive style have distinguished prediction.

Keyword: **cognitive style, virtual reality, learning transfer**

1 Introduction

A highly concerned subject to educators is how to enhance the outcome of education. In nearly a century, the researchers of educational technology are trying to find out the best educational media to assist their teaching. Educators expect the learner can learn effectively in short time. Because of individual difference, several factors could affect final achievement, including physiology, psychology, cognition, the attitude of educator, and the learning environment. As a result, the relationship between educational technology and the learning effect always being questioned.

Under the trend of "global life-time learning", distance learning has become a new learning model. It is excited that the technology shorten the distance between teaching and learning. Moreover, the interaction among virtual reality makes the communication possible between the real world. The researchers are aware of the potential of virtual reality. They believe the functions of simulation, interaction, and involvement of multi user leads the virtual space towards the model of virtual community. However, the reality and the virtual world have to coexist. The problems in real world have to be solved. It is important to consider how to make good use of the characteristics of virtual reality learning while trying to set up a virtual learning environment. We can not put every learner under virtual learning world(Chu,1998). Lin(1997) believed a well-designed hypermedia helps learning. Furthermore, it has positive impact on the attitude of the learner using hypermedia.

The characteristics of the learning media and the learning attitude of the media are both variables of the cognitive style used to predict learning effects. Therefore, the objective of this study was to assist junior high school student study drawing in living technology education by using virtual reality. In addition, the impacts of the different cognitive styles on the learning using virtual reality are investigated. Student's adaptation of cognitive styles to the new media was discussed.

2 purpose

The purpose of this study is to discuss the transition of virtual reality learning transfer with different personal variable, cognitive need, cognitive style, and computer attitude. To summarize, the purpose of this study is follow: (1). To inquiry the influence compared with different personal variable, cognitive need, cognitive style, computer attitude and VR learning transition. (2) To explore the influence between personal variable and cognitive style. (3). Beside on the result and finding , to provide the concrete suggestions for teachers and people who design the environment of web virtual reality .

3 Method

3.1 Subject

Cluster sampling was used in this study. Two schools, Kwan Hwa Junior High school and Youth Junior High school, were selected for sampling. After the rejection the invalid samples 133 students are analyzed.

3.2 Materials

3.2.1 Cognitive Style Profile

To explore whether student with different cognitive styles react differently to the same material, this research adapted the Cognitive Style Profile that was developed by Keefe and Monk (1979) and translated by Liu (1992). The result of this profile is to investigate students' cognitive style in several dimensions. Scales between poor to excellent were measured to separate students into several groups. Factors as sequential processing skill (SQP); discrimination skill (DS); categorization skill (CS); analytic skill (AS); spatial skill (SS); memory skill (MM); and verbal spatial preference skill (VSP) are discussed.

3.2.2 The Need for Cognitive Scale, NCS

The NCS scale developed by Cacippo and Petty(1984) and translated by Cheng-Ren Zhan (1997) was used here. Research showed NCS had high positive correlation with IQ and low positive correlation with cognitive style.

3.2.3 Computer Attitude Profile

Ming-Long Wu (1997) developed the "Computer Attitude Profile" to investigate the computer attitude tendency of students. This profile includes four dimensions: computer affection, computer application, confidence attitude, and gender differences.

3.2.4 The learning classroom of virtual reality

This study adapted the " The learning classroom of virtual reality " which designed by Jia-Rong Wen (1999) (NSC 88-2520-s-017-001). Contents cover "Technology education--show visions". "The learning classroom of virtual reality" is divided into four areas: direction, disappeared-point, three visions and heap. The relationship between teaching materials and cognitive style is as the right side.

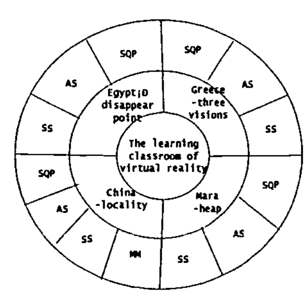

Figure 1 The relationship between teaching materials and cognitive style

3.3 Experimental design and procedures

The learning process of virtual reality in this research was divided into five steps: (1) The input of basic personal data; (2) Profiles Test; (3) pretest; (4) Virtual reality learning; (5)Posttest.

About the path of this framework , describe as follow:

A. To explore the relationship between personal various and VR learning transfer.
B. To inquiry the relationship between cognitive need and VR learning transfer.
C. To investigate the relationship between computer attitude and VR learning transfer.
D. To study the correlation between cognitive style and VR learning transfer.
E. To understand the effect of between personal various and cognitive need, computer attitude, and cognitive style.
F. To investigate the distinguished predictive force with cognitive style, cognitive need and computer attitude toward VR learning transfer.

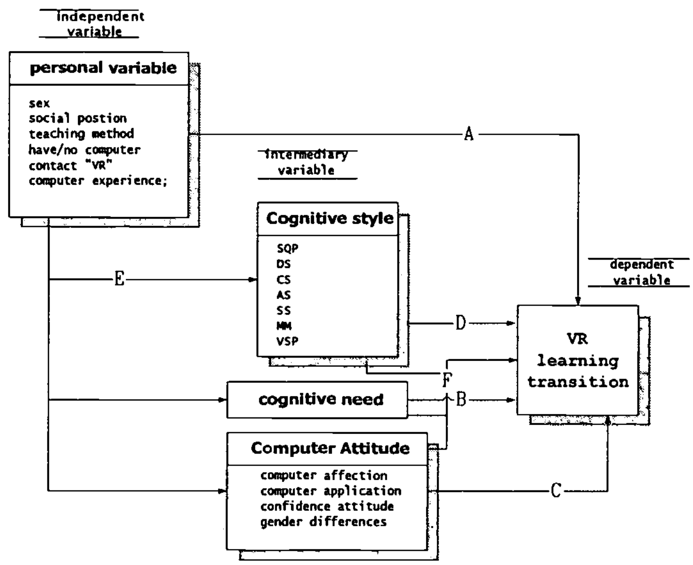

Figure 2 The framework of research

4 Results and Discussion

After the test, the collected data was analyzed in statistical methods such as T-test, one-way ANOVA, correlation, MANOVA,regression and the Scheffe test; the report, based on the results and discussion, is as follow.

4.1 descriptive illustration

4.1.1 The present situation description of cognitive style

Table 1. The present situation description of cognitive style

Cognitive Style	Mean	SD	TSTANDARD SCORE RANGES				
			weak	Lower than mean	mean	High than mean	strong
SQP	52.12	8.28	12	13	27	81	0
DS	44.72	12.24	33	22	30	40	8
CS	59.7	7.67	0	11	8	50	64
AS	51.28	9.71	30	35	0	24	44
SS	53.15	9.26	21	33	0	31	48
MM	53.98	10.29	10	29	17	36	41
			Space	Neutrality toward space	neutra lity	Neutrality toward language	language
VSP	45.39	7.29	21	68	30	10	4

As the Table 1, show the situation of junior high school students about cognitive style. Students have excellent skills in SQP, CS and MM. Students are short of DS skill. The mean of DS skill is lower than 50 and the SD is higher score, to display students have large different in DS skill. Both AS and SS have twin-peak distribution patters. VSP indicates the habit and perference of personal learning styles. From Table 1, the result shows that most of the subjects are used to or prefer spatial skill rather than verbal skill.

4.1.2 The present situation description of computer attitude

Table 2. The abstract description of computer attitude

	mean	SD	number	Mean of number
Computer affection	31.06	6.06	8	3.88
Computer application	54.71	8.61	13	4.21
Gender differences	23.86	4.78	8	2.98
Confidence attitude	19.05	5.86	7	2.72

According to Table 2. ,the mean of number approximate 3 to confirm the information spreading effect in these years. "Computer application" is higher and "confidence attitude" is lower than others. Study displays Junior High School students have bad confidence toward computer attitude.

4.2 The relationship of VR learning transfer with personal variable, cognitive need, and cognitive style

4.2.1 Test of significance of different personal variable for VR learning transfer

Table 3. The abstract of T-test of significance about personal variable in VR learning

Basic personal variable	classification				T_test	Scheffe
	Mean	SD	Mean	SD		
sex	male (67)		female (66)			
	6.57	11.05	6.36	11.32	0.105	
Have computer at home	have(86)		no(47)			
	9.07	10.42	1.70	10.95	3.829***	have > no
Have contact with 3D VR	have(45 □)		no(88 □)			
	7.78	10.47	5.8	11.47	0.807	

*P<.05 **p<.01 ***P<.001

Table 4. The abstract of ANOVA of significance about personal variable in VR learning

	Mean	SD	Mean	SD	Mean	SD	Mean	SD	F	Scheffe
socio-economic level	2(33)		3(42)		4(58)				4.017*	2 > 4
	10.30	9.27	7.26	11.80	3.71	11.06				
train	authority(3)		freedom(3)		assistance(3)		Other(4)		2.382	
	1.76	11.58	8.29	10.56	6.25	11.37	0.00	11.40		
Computer experience	Less 1 year(1)		1-1.9 year(2)		2-2.9 year(3)		More 3 year(4)		1.318	
	5.17	11.77	8.52	9.49	6.68	12.52	10.83	7.93		

Ps: 2:high socio-economic level ; 2:middle socioeconomic level; 4:low socio-economic level

According to Table 3 and Table 4, to show the basic personal variable influence VR learning transfer. "Have computer at home" and "socio-economic level" influence VR learning transfer directly. Those students whose families are at higher social or economic levels perform better in VR learning transfer. Their parents usually pay more attention to their environment of education and afford computers in their own homes.

4.2.2 Test of significance of different personal variable to cognitive style and computer attitude

Table 5. are the results of MANOVA comparing with different socio-economic level and computer experience. It shows that higher socio-economic level students get high score on DS.

In Cognitive Style Profile, students from families of different social or economic levels have significant difference (p<0.05) in DS. Moreover, after having applied Scheffe Mathod, those who are from higher social or economic levels ahve better DS than those who are from middle levels.

Table 5. The abstract of significance of MANOVA about socio-economic level

socio-economic level	1 (38)		2 (75)		3 (10)		Wilk's	F	Post compare
	Mean	SD	Mean	SD	Mean	SD			
SQP	3.36	0.86	3.29	1.02	3.34	1.04		0.068	
DS	3.03	1.29	2.31	1.24	2.93	1.25		3.992*	2>3
CD	4.36	0.90	4.21	0.95	4.22	0.88		0.313	
AS	2.88	1.73	3.50	1.57	3.00	1.61	0.845	1.665	
SS	3.73	1.57	3.52	1.49	3.10	1.57		1.941	
MM	3.70	1.24	3.50	1.31	3.43	1.40		0.423	
VSP	2.48	0.97	2.40	0.91	2.14	0.91		1.813	
								1.556	
computer affection	32.06	5.23	32.14	6.31	29.71	6.13	0.896	2.633	
computer application	55.73	7.35	55.81	9.54	53.33	8.52		1.326	
gender differences	16.36	5.81	19.48	5.77	20.28	5.55		5.150**	4>2
confidence attitude	24.33	3.93	24.45	5.63	23.17	4.54		10.84	
								1.786	

In Computer Attitude Profile, students from families of different social and economic levels also ahve different profermance in the dimension of "gender differences".On the Contrary, those who are from lower social or economic levels have greater differeces between genders.This suggests that the male from lower social or economic levels have stronger stereotype about "computers are particularly for the male".

4.3 The relationship between cognitive style, cognitive need, computer attitude and learning translation

Table 6. The abstract of significance of ANOVA about cognitive need and computer attitude toward learning translation

	Mean	SD	Mean	SD	Mean	SD	F	Scheffe test
Cognitive need	1--lower(37)		2--middle(62)		3--higher(34)		3.247*	3>1
	3.78	10.50	5.97	12.51	10.29	7.97		
Computer attitude(3 in 1)	1--lower(31)		2--middle(72)		3--higher(30)		6.759*	3>2;3>1
	2.58	10.64	5.69	10.82	12.33	10.40		
computer affection	1--lower(40)		2--middle(54)		3--higher(39)		2.542	
	3.25	11.80	7.41	9.94	8.46	11.59		
computer application	1--lower(34)		2--middle(60)		3--higher(39)		3.535*	3>1
	2.79	9.86	6.5	11.80	9.62	10.41		
confidence attitude	1--lower(34)		2--middle(63)		3--higher(36)		2.049	
	3.68	10.89	6.51	10.42	9.03	12.24		
gender differences	1--lower(34)		2--middle(53)		3--higher(46)		0.449	
	7.35	13.10	6.98	10.02	5.22	10.95		

Table 6 shows that personal cognitive need affects VR learning transfer ($F=3.247$; $p<0.05$).After having applied with Scheffe, those with more cognition need have better VR learning transfer than those with less Need(3>1).

Table 7 shows the effect upon several dimensions in cognitive style toward VR learning transfer. From the result, those with "Strong" and "Higher Than Mean" DS have better in VR learning transfer than those with "Lower Than Mean" DS. In other words, DS and VR learning transfer are somehow associated. SS and learning transfer are also associated since they show significant differences. After having applied with Scheffe, those with "Strong" SS ahve better in learning transfer than those with "weak" SS.

Table 7. The abstract of significance of ANOVA about cognitive style toward learning translation

level	1 Weak		2 lower than mean		3 Mean		4 higher than mean		5 Strong		F	Post compare
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD		
SQP	6.67	10.30	1.15	11.02	8.33	11.27	6.67	11.18			1.255	
DS	4.24	12.26	-0.45	11.84	8.00	9.79	9.25	8.44	15.0	11.34	4.91***	5>2;4>2
CS			10.0	14.49	8.13	8.43	4.50	12.34	7.19	9.71	1.037	
AS	5.50	10.28	8.14	10.99			6.04	13.02	6.02	10.97	0.369	
SS	0.95	11.69	6.67	11.57	7.67	12.13	7.22	10.31	5.24	12.04	2.804*	5>1
MM	7.50	5.89	6.21	12.08	7.65	12.13	7.22	10.31	5.24	12.04	0.232	
VSP	4.76	12.60	7.21	10.01	5.33	11.37	8.50	15.47	6.25	11.81	0.352	

Table 8. The relationship of cognitive style, cognitive need, computer attitude with VR learning translation

	SQP	DS	CS	AS	SS	MM	VSP	Cognitive
Learning transfer	.056	.226*	.073	-.024	.221*	.009	.068	.051
	Cognitive need	computer affection	computer application	confidence attitude	gender differences	Computer attitude(3 in 1)		
Learning transfer	.245**	.188*	.186*	-.058	.218*	.244**		

In Cognitive Style Profile, DS and SS are highly associated with VR learning transfer ($p<0.05$). The correlation coefficient are 0.226 and 0.221 respectively. In the VR learning transfer of the subjects, the variances accounted by DS and SS are 0.5 and 0.48 respectively.

The Need for Cognitive Scale and VR learning transfer are significantly associated ($r=0.245, p<0.01$) with a variance at 0.06.This indicates that those with higher Cognitive Need tend to perform better in VR learning transfer. In the Computer Attitude Profile, only the dimension "gender differences" is staticstically independent from VR learning transfer. The rest dimensions of the profile are significantly positively associated with VR learning transfer.

This shows that it is easier for those with positive attitide toward computers to have more VR learning transfer.

4.4 Stepwise Multiple Regression

In the analysis of Distinguished Predictive Force of variables, Stepwise Multiple Regression was used with VR learning transfer as the dependent variable. And the independent variables included seven dimensions of Cognitive Style Profile (which are SQP, DS, CS, AS, SS, MM, and VSP), four dimensions of Computer Attitude Profile and NCS. The result shows on table 9.

Table 9. The Stepwise Multiple Regression table

order	R	R^2	ΔR^2	β	F
1.cognitive need	.245	.060	.060	.110	8.386**
2.DS	.328	.108	.048	.267	7.842***
3. Computer attitude(3 in 1)	.387	.150	.042	.219	7.569***
4.SS	.430	.185	.035	.198	7.247***

Within the thirteen independent variables, four of them show significance in Distinguished Predictive Force. They are NCS, DS, CA, and SS. They altogether can explain 18.5% variance in VR LEARNING TRANSFER. When only one single independent variable is effective, the distinguished predictive force of NCS is the best, which reaches 6%; DS accounts 4.8%; Computer attitude(3 in 1) predicts 4.2%; and SS only score 3.5%.

4.5 Synthetic analysis about VR learning transfer

After analysis,table 10 shows the result of comparison. As follow:

Table 10. The synthetic analysis about VR learning transfer

	Cognitive need		Computer attitude				
			Computer attitude(3 in 1)	computer affection	computer application	confidence attitude	gender differences
VR learning transfer	3 > 1		3 > 2 3 > 1		3 > 1		
	Cognitive Style						
	SQP	DS	CS	AS	SS	MM	VSP
VR learning transfer		5 > 2 4 >2			5 > 1		

Table 10 shows the facts which effect VR learning transfer. Those are "cognitive need"□" Computer attitude(3 in 1)"□" computer application" and cognitive style (DS and SS).

5 Conclusion and Suggestions

5.1 Conclusion

Distance education offers a new chance applying to review learning conviction and learning tactic for developing learning environment. Virtual Reality is an important style for distance education. In this study, the relationship of learning translation with cognitive style, cognitive need and computer attitude is concerned. The main results of this study are as follow :

(1).The cognitive style of students is generally good and above medium level, however, it seems not very good at discrimination skill.

(2).The verbal spatial preference skill of students leans toward the spatial learning.

(3).The computer attitude of students is good generally and has positive attitude.

(4).The social position and owning computer have a remarkable influence on the VR learning transfer; yet sex, learning computer experience and family education mode do not have a distinguished influence on learning.

(5).Increasing the opportunity for students to use computers helps VR learning transfer by computers.

(6).The VR learning transfer differed by the difference of cognitive need.

(7).The number of computer attitude will influence VR learning transfer, that one having positive (computer) attitude is much more efficient than the negative.

(8).Discrimination skill and spatial skill will influence the VR learning transfer.

(9).The number of different personal factor have a remarkable influence on cognitive style, cognitive need and computer attitude; yet family education mode does not have a distinguished influence on them.

(10).The discrimination skill, spatial skill, cognitive need and computer attitude have a remarkable positive correlation with the VR learning transfer.

(11).By means of predictive analysis, attitudes in computer, cognitive need and cognitive style have distinguished prediction.

5.2 Suggestions

According to the result of the research, we request the following suggestions to the related authorities in educating long distance of virtual reality reference:

(1) Among the seven items of Cognitive Style, students in domestic have better skills in sequential processing, categorization and memory; while in discrimination skill, the average is lower, and there are more differences inside. According to the explanation of the scale which evaluates the students whether they can focus on some level. The ones will high grades have better special quality on the focusing in cognitive styles, sharply watch the proper details and grasp the key points at work. The grades of students become lower is possibly due to fewer focusing on learning.

(2) The combinded resources of communities and schools can contribute to the education of the students from families of lower social or economic levels. In addition, the bond between the communities and the schools can provide various opportunities for students to operate computers.

(3) To increase students' oppertunities of active observation and to enhance their abilities in science and technology.
(4) To progress students' DS and SS, to benefit their VR learning transfer.
(5) To promote students' confidence in operating computers, to develop positive attitude toward computers, to enhance learning, to increase VR learning transfer the stereotype of gender differences should prevented
(6) To accommodate Spatial Learning, to escalate VR learning transfer.
(7) To let students establish the positive cognitive demand is more helpful to VR learning transfer.
(8) The computer attitude is also the important factor of VR learning trandfer. Students with positive confidence in believing computer is a kind of assit-tool have better learning effect.

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The Externalization Support System of Self-explanation for Learning Problem-Solving Process

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When a learner dose various tasks in the computer, the interaction of the learning support system is so a transition which happens inside the learner. At that time, educational effects such as knowledge structuring occurs due to externalization of representation. We developed the prototype system in so that externalization of self-explanation of the problem-solving process was supported. A learner externalizes the self-explanation "How do I solve the exercise?". At this time, she/he explains using not only words but also diagrams, in order to exploit the effect of diagrams. Self-monitoring happens with self-explanation, and the acquisition of a problem solving strategy on is learned. In this paper, we construct a model of "externalization on the computer," and we consider the occurrence of cognitive load. Learning is a kind of load, therefore any reduction of the load (as opposed to its extinction) is of assistance. We propose the presentation of an operation list as a method of load reduction. The memory dependent evaluation becomes more coherent by such a list. In other words, the cognition perspective improves. In this paper, it is shown in the prototype system how externalization is accomplished.

Keywords: **Self-explanation, Reflection, Externalization, HCI**

1 Introduction

Recently, the contents of interaction have been reconsidered in the context of the learning support system[1]. So far, a computer playing a teacher's role is aimed at the transfer of domain knowledge expressed by the system. The computer asks a learner several diagnostic questions. The computer is central to such interaction. The perspective "For whom is this interaction?" is absent. In this paper, we propose an learnig environment (externalization support system) that promotes the understanding of problem solving resulting from the externalization in the computer. The learner works independently on the computer with the interaction we propose, then the learner rewrites his internal state. Learning occurs at that time.

Recently, attention has focused on "externalization " and "meta-cognition." For example, a vague idea is sometimes clarified by writing text. Externalization promotes the arrangement of knowledge and learning. On the other hand, meta-cognition is a psychic activity of higher order, involving self-monitoring (reflection), and is concerned with deep level learning such as the acquisition of strategies, the transfer of knowledge.

We paid attention to the self-explanation of the problem-solving process, and we have researched that support[2]-[3]. At present, a learning support system that externalizes self-description of the problem-solving process has been utilized as an experiment. Exercises in statistical scales of geography were used. A learner expresses how she/he solved a problem. Geography though is considered mere memorization, the learner can acquire an understanding of the problem-solving process by self-description. An example of this type of exercise is shown in figure 1.

We propose the usage of figure 1 as a method of externalization. We are constructing the environment where a learner can do self-explanation by writing memoranda. In this system a learner draws on the character and diagram of the explanation of the problem-solving process. Furthermore, the examination process of externalization is supported from the cognition perspective. The activities scrutinized are internal (understanding the behavioral reason of the learner) and are supported by the presentation of the operation history. This supports the self-monitoring that is crucial to meta-cognition

Idea support system, idea sketch, etc. are proposed in the HCI researches. However, we think learning involves a kind of load, and our purpose is to recommend support by control of the load, rather than by elimination of the load. The consideration of support by reduction of the load is a different point.

In chapter two, we describe the educational effect of externalization. We propose a support method of externalization targeting self-explanation of the problem-solving process in chapter three. The summary of our system is shown in chapter four. We present a summary in the final chapter.

2 The outline of externalization

2.1 The educational effect of externalization

Many researchers point to the educational effect of externalization[5]-[6]. The effect of diagram use in externalization has been acknowledged as well. The learner can acquire the educational effect if self-description is externalized by use of diagrams[7]-[8].

Externalization is the expression of internal psychic activities (images). We mention clarification of knowledge, structuring, etc. as a general effect. Moreover, internalization occurs by repeated externalization, and internal processing proceeds smoothly.

Self-description involves special explanation of a point[9]. Externalization is unique as well. Self-monitoring is enhanced by a learner's repeated externalization of the self-explanation.

2.2 Externalization model on the computer

We construct a model of externalization in this section; our objective is not to clarify the mechanism of externalization. In a sense, the model is to employ educational effect. Various models of externalization are available; we have elected to choose a model of externalization in the computer.

Externalization is considered to consist of several functional modules. The module described here is the functional unit that is comparatively independent.

The model of externalization and the state of repetition of each module are shown in figure 2. We classify modules of externalization into four ways.

(1) Image generation
(2) Expression form generation
(3) Operation sequence generation
(4) Examination (evaluation)

Module (1) is the creative impulse that forms an internal image. Externalization consists not only of the creative impulse of expression but also of the underlying representation. Though module (1) is a heterogeneous activity, it is a part of externalization. Creativity is a very complex psychic activity, and is beyond the scope of this paper.

Module (2) is the expression of vague internal images. Expression is based on the rule

Question: What are items(1),(2),(3)?

Item	Ranking	1	2	3	4
(1)	Exporting country Amount of export	U.S.A 9,637	Australia 5,300	Poland 2,800	U.S.S.R. 2,000
	Importing country Amount of import	Japan 7,909	France 2,295	Italy 1,905	Canada 1,567
(2)	Exporting country Amount of export	Cuba 675	France 300	Australia 255	Brazil 253
	Importing country Amount of import	U.S.S.R. 672	U.S.A. 270	China 222	Japan 180
(3)	Exporting country Amount of export	Japan 1,612	West Germany 1,458	France 675	Belgium* 460
	Importing country Amount of import	U.S.A. 1,802	England 490	West Germany 483	Italy 460

(1)and(2)unit is 10,000 tons. (3)unit is 10,000,000 dollars. *:Includes Luxembourg.
(1):1982, (2):1983, (3)1980

Fig. 1 Example of geographical exercise.

of generation. As a case in point, form of presentation (rule) that has been configured freely and formalization that has already been completed, may be employed. For example, in the case of pictures, expression is free, and a person who draws a picture decides the form of presentation. On the other hand, when we illustrate a phenomenon with a formula, formalization is predetermined, and we must obey mathematical rules. As for externalization of writing memoranda, existing formalization and independent formalization are being used together. We can think of module (2) as consisting of the following three usage forms.

(a) Existing formalization
(b) Independent formalization
(c) Existing formalization + Independent formalization

The burden of usage of the existing formalization is that a learner must understands formalization. However, when a learner acquires existing forms, internalization progresses, and the representation in module (1) becomes simplified. For example, when a learner is skilled in the use of the Japanese abacus, she/he becomes capable of mental arithmetic using a mental image of the abacus. The effect of the Venn diagram in the understanding of the set theory is similar.

When externalization is done on the computer, the process of module (3) is remarkable. The rate of this part increases when the expression is done indirectly using the computer. Expression can't be generated if the computer lacks the appropriate software. Thus, a learner plans an operation sequence to configure expression, and she/he will move the mouse based on that plan.

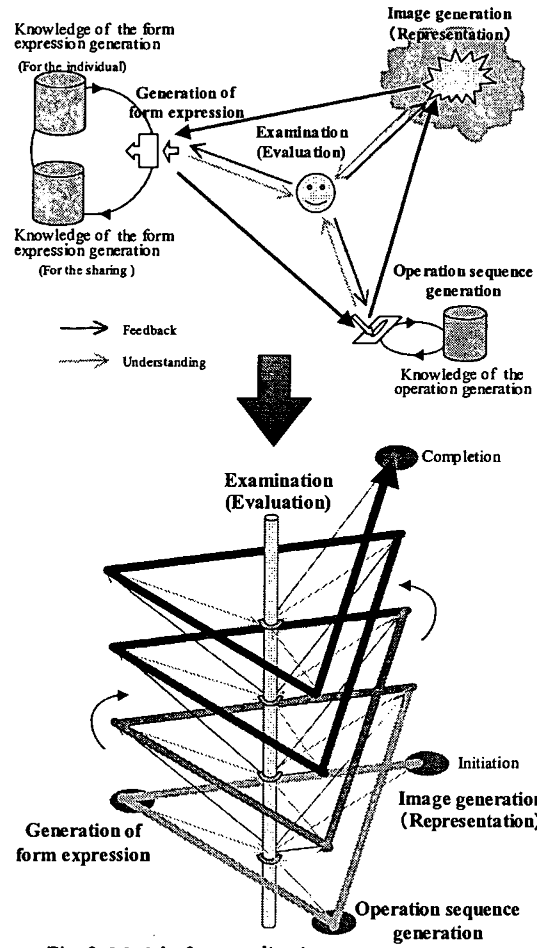

Fig. 2 Model of externalization on the computer.

Module (4) is different from the other modules. Examination is the evaluation of each process from module (1) to (3) with feedback. In other words, examination is a meta-level activity when compared with the other processes.

Modules (1) to (3) become a cycle. The processes from (1) to (3) are evaluated by process (4), which provides feedback. This cycle is repeated until a learner judges by examination. That the activity has been completed

3 Externalization support of self-explanation

3.1 The support of externalization by load reduction

The general support method of externalization is considered in this section. First, we remove the cognitive load intuitively for externalization support. However, the purpose of learning is to put load on the learner. Even if a computer estimates the intention of the learner (even if an explanation is formed automatically,) learning does not progress. Hence, removal of the load does not support learning.

The real nature of the load lies in the multiple combinations of the loads. The load is classified by cause and category, it is necessary to separate the load that aids learning from the load that does not. We aim to reduce the load. In other words, consideration of the relevant control of the load is necessary. Arrangement and classification of each load is necessary for its support.

3.3 Drawing method of the problem-solving process

Support of the expression form generation process serves to prepare for the effective expression method. We show (by way of drawing) the problem-solving process following. Problem-solving is a process, and it has a certain structure. Diagram usage is effective to express structured information. Graph expression is a relevant method like Tweedier's indication as an informational expression that has a flowing structure[10]. For example, though various methods are proposed, a flow chart is still used for the expression of a program structure.

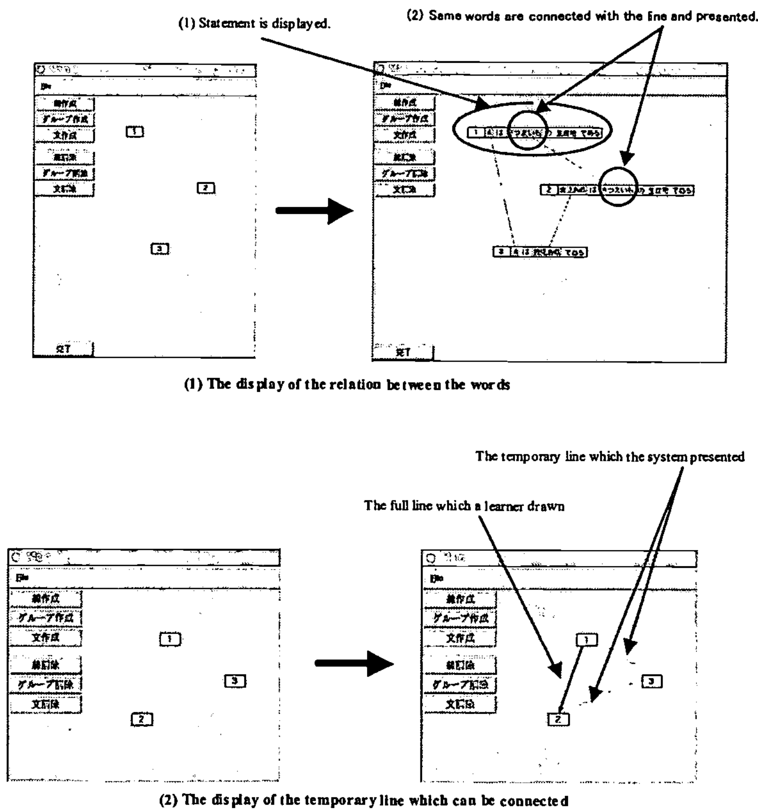

Fig. 3 Model of operation support.

We use a style that combines the use of words and figures. We propose the arrow diagram that expressed structure between statements was symbolically used with the text of the items together. The externalization task with our learning environment consists of two tasks: text creation and graph drawing. Expression is constructed in the following procedures:

(1) The Entering of a simple sentence
+
(2) Placement (migration)
(3) Connection
(4) Grouping
(5) Attribute addition to the object

First, a learner constructs the explanation of the character form. The explanation of the solution reflects the problem-solving process of the exercise. We exclude compound sentences and complex sentences, and use only simple sentences. Each simple sentence during expresses each state of the problem-solving process. A learner is conscious of the order, and notices that problem-solving proceeds by the items. The order of the explanation copes with the process of the problem-solving.

Next, each simple sentence is connected with an arrow line to form a "node". A learner is specifically conscious of the structure by drawing these lines. As for the structural expression of the explanation, each statement is associated with the arrow line toward the explanation of the expressed goal from the explanation of the initial state. A learner encloses some statement, and gives color attribute as a supplementary activity. The diagram drawn with the arrow line is completed by repeating the above activity.

The part that decides expression is first and the part in which a learner himself can determine expression are both present in the above expression method. Such a method guarantees freedom of expression for the learner, while at the same time accepting ambiguity. Thus a learner can write a memorandum of the meaning of the attribute appended by the learner. For example, the system asks a learner for a reason when a learner changes the color of the line. This function is actualized as a fraction of the support of the look-over.

3.4 The support of the operation sequence generation

We describe the support of the operation sequence generation in this section. The following function is provided because the learning environment should be made convenient.

(1) The simplification of the operation
(2) The intersection of the operation and the phenomenon

The operations of the learning environment are statement creation, statement delete, line drawing, line erasing, movement, grouping, and the color alteration of the object. It prepares only for easy operations. A phenomenon can be easily imagined from these identifiers. We achieve a single function in our system. An operation and a phenomenon correspond one-to-one, and the understanding of the operation becomes easy.

The learning environment is tailored to notify the learner of deficient explanations and feasibility of the expression by the following operation support. The state of the support is shown in figure 3.

(a) The display of the related word information
(b) The display of drawing line feasibility

A simple sentence is displayed on the learning environment as a symbolic icon. One component is made according to statement, a learner can focus on structure between the statements. On the other hand, a certain word sometimes has significant meaning for structural grasping of the explanation. The learning environment manages word information, and employs it for support.

The indication of related word information This is the method in which the structural understanding of the statement is accelerated. When the same word in is used several statements, the learning environment shows them. When the same word is shown repeatedly, the system is made conspicuous. The system displays a statement next to the statement icon, and gives color to that word. The same word in different statements is connected by a line.

The indication of connection feasibility This is the method in which drawing between the statements is supported. The system presents the link that can be connected in the statement nodes as a temporary line. The system estimates the statement that relate to other statements in the placement step (which the statement icon on the workspace finished). The feasibility a line drawn is high in the statement which satisfies the following conditions:

(A) The statement operated just before
(B) The statement that encompasses the same word

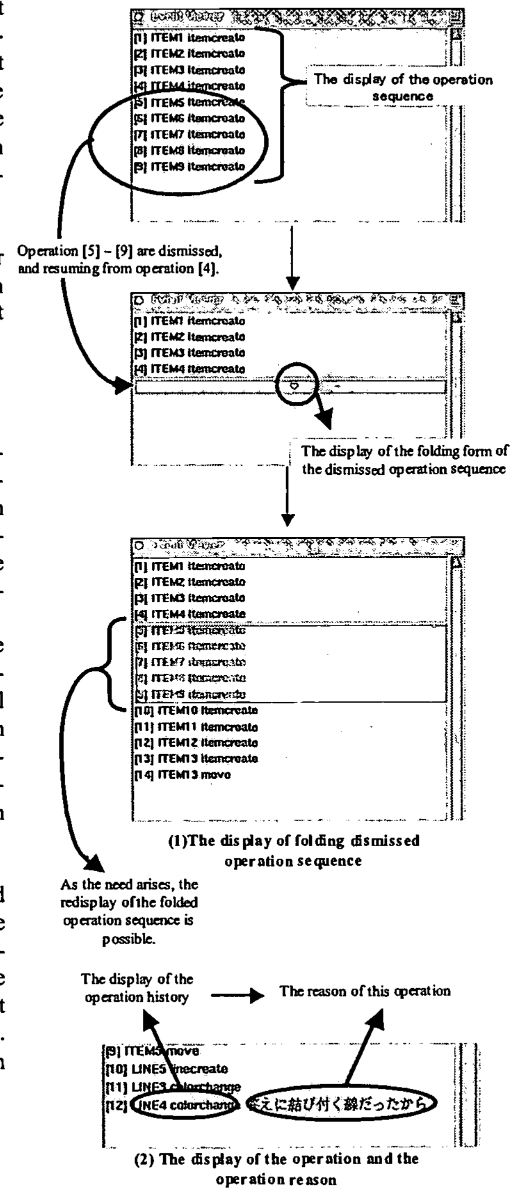

Fig. 4 Representation of the operation history list.

The system presents a temporary line to the learner according to the stage at which placement was finished. All candidates are displayed when some lines are presumed. When a learner chooses a temporary line, the system re-establishes that temporary line as a permanent line. Because drawing lines is a possible option, the work of drawing is reduced for the learner.

3.5 The support of the examination by cognitive perspective

We aim at the realization of the farsightedness of the cognitive perspective with the support of examination. Externalization is done so that a learner may learn about himself. We aren't aiming at deputy by the system. The approach of automating conception and drawing isn't embraced. Support toward examination of evaluating one's act is necessary. Therefore, we propose a method that assists the self-monitoring by the learner. The system uses the following two methods, as shown in figure 4.

(1) The display of the operation history
(2) The collection and display of the operation reason

Reflection on the personal task must depend on the current aspect of the activity subject and on memory. However, subject activity does not express variations in the middle of the task. Moreover, memory is often a temporal effect, and often can't be extracted when necessary. Therefore the system preserves task history, and history and task process are reproduced to the learner. The system makes linear operation sequences and a learner can do an operation again from the arbitrary juncture of the operation sequence that is presented. In that case, a recent operation sequence occurs from the point that an operation was done again, and a previous operation sequence is dismissed.

However, when a learner reflects on an error, dismissed operational sequences encompass significant information. Because reflection support is critical, the system preserves all operation sequences. When a recent operation sequence occurs, the previous operation sequence is hidden temporarily from the learner. Then, if a learner requires, the previous operation sequence can be displayed. Cognitive perspective in the examination process improves due to the presentation of the operation history.

The display of the operation history provides an opportunity to look back at the operation. Furthermore, we not only present operation history but also present the reason of the operation. The system requires comment input at every operation. The set list of the operation and the reason are stored in the system. It is understood that comment is useful in order to reconsider program source. Ambiguity is present in expression, and the degree of freedom of expression is guaranteed. A learner himself sometimes forgets the intention of the figure on one side. A memorandum of the operation is useful in such a case as well. The presentation (collection) of the memorandum of the operation is not the active intervention of the system.

4 Self-explanation externalization support system

4.1 The configuration of the self-explanation externalization supporting system

Our system before this paper externalized a self-explanation only in character[3]-[4]. However, figures and text are mixed in the natural externalization. Drawing activity is separated from text creation activity in self-explanation, and it is unnatural to draw after text is written. Therefore our system was designed to enter text and to draw simultaneously.
We implemented three functions in the system.

(1) Explanation management
(2) Explanation structural management (visualization management)
(3) Operational history management

Module (1) manages information on the explanation sentence. This module is shared the entry of the explanation sentence and the display of the explanation sentence. A learner enters a simple sentence. The morphological analysis of each simple sentence is done by "Cyasen" developed with NAIST. Information on the word is extracted. By this processing, information on the noun and verb in a simple sentence is extracted. The system preserves the information with a simple sentence.

The order of the statement input can't be employed as an order of the explanation sentence. When a learner completes a drawing, the system decides the order of the explanation sentence based on the following information:

(a) Related to the arrow
(b) Grouping
(c) Related to the place
(d) Input order

First, the system gives priority to arrow line information. The beginning point and end point of the arrow shows a context. Next, simple sentences are grouped to the same level. The system fundamentally introduces the order of the input as the order of the explanation. When there is no grouping or arrows in the explanation figure, the system decides the order of the explanation sentence based on the co-ordinate information of the icon on the "canvas "screen. If there is a top-to-bottom relationship among icons, this relationship becomes the context. The order of input is used except in the case above. After the system shows the order, the alteration of the order by the learner is possible.

Module (2) manages the drawing task and the information acquired from this task. A learner enters a simple sentence, and next drawing becomes possible. Module (2) manages the whole drawing task on the "canvas", and it displays support information.

Module (3) presents the task history (operational history) of the learner. A learner sees this operation history, and adds various modifications to the externalized figure.

Various methods of presentation of the operation history are proposed. We think the list form is easy to understand. Various methods of Undo (Redo) are proposed as well[11]. We consider an operation to be a series of persistent sequences. We introduce the interface in which an operation can be done from an arbitrary part of the operation history list and the previous sequence folded under the recent sequence. The current sequence is important for the learner, so a dismissed sequence is rendered temporarily invisible. Hidden operation history can unfold the folded part if necessary (the icon indicates it has been folded.), but a learner only confirms a folded operation sequence, and a dismissed sequence can't be redone midway in the process.

4.2 Outlook of the system

We show how self-explanation is externalized on the system in this section.Six windows are displayed in the system that was manufactured. The screen configuration of the system is shown in figure 5.

(1) Canvas window (Operation button is encompassed.)
(2) Simple sentence input window
(3) Explanation sentence display window
(4) History panel
(5) Operation memorandum input window
(6) History display window

A learner does a drawing task on the canvas window (1), and then the drawing consequence is displayed. The learner starts an explanation through this window, and the explanation is written and modified. Various operation buttons are configured. This window performs the role of the console panel of the whole system.

The simple sentence input window (2) is a one-line editor for a learner to input a simple sentence. This window is invoked by the sentence-creation button on the canvas window, and closes when the input is finished.

The explanation sentence display window (3) displays an entered simple sentence with the items. Each sentence is displayed on this window by an entered order. When a learner estimates that externalization has been terminated (the stage in which the "completion" button is pushed), the order is evaluated, and the line of the explanation sentence is replaced. However, a learner can alter the line of the explanation sentence by using the mouse to "drag & drop".

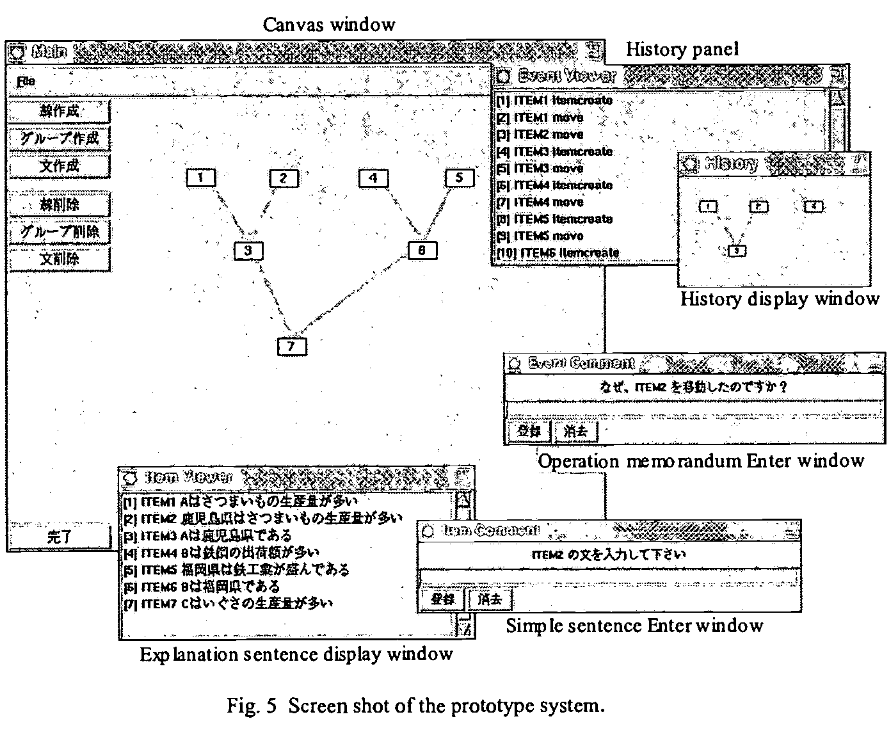

Fig. 5 Screen shot of the prototype system.

The history panel (4), the operation memorandum input window (5) and the history display window (6) are related mutually. The operation history of the learner and memoranda are displayed in the history panel. Though the memorandum input window is displayed at every operation, a learner doesn't necessarily need to enter memoranda. Entered comments are displayed in the history panel with the associated operation. When a learner chooses an operation from the operation history, the history display window displays the screen image when that operation is done. It is important to simultaneously present the screen image to support cognitive perspective. Moreover, if a learner chooses an operation from the operation history, she/he can redo the operation from there.

5 Conclusions

In this paper, we described a learning system in which externalization of self-explanation of the problem-solution process was supported. Recent attention is founded in the educational effect of externalization; however, the mechanism of externalization isn't clear, and the recommendation of the usage method isn't sufficient, either.

Therefore, we surveyed externalization first, and described the educational effect. Next, we considered the support method of externalization, and proposed the support method of externalization of self-explanation. The first is the method of externalization of self-explanation that employs expression by words and diagrams, such as memoranda. The other method is that of collecting the operation history and presenting it to the learner from the viewpoint in which the cognitive perspective is important for the examination process of externalization. Furthermore, we attempted a system that could leave operation reason when the operation history was collected. Self-monitoring becomes smooth by presenting operation and reason. Finally, an overview of our trial production system was shown. The state in which a learner externalized in that system was shown.

In the future, we will improve the system, targeting each operation to reduce user load, and we will evaluate the system.

Acknowledgment

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The Use of Animation as a Tool for Concept Learning

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The purpose of this study is to investigate the effectiveness of animation as a tool for concept learning, based on the Media ZPD Model, and provide insight to ensure the quality of video, CD-ROM, and Web-based instructional materials. The design includes two independent variables: Presentation Method (Animation, Still-visuals, and No-visuals) and Audio Mode (Audio and Silent). Through randomization, 144 5th-graders were assigned to one of the six groups. The Group Embedded Figures Test (GEFT) was first given. Next, variations of the visuals, "Cube," were presented. Then, a posttest was administered. The results indicated that two Audio Modes (Audio and Silent) have no significant difference. There is an interaction between the GEFT and the presentation methods. The analyses showed that for Field-dependent (FD) learners (1) Animation and Still-visuals have no significant difference; (2) Animation is significantly higher than No-visuals; and (3) Still-visuals is also significantly higher than No-visuals; For Field-independent (FI) learners, different ways of presenting visuals have no significant differences. There is a positive and moderate relationship between the posttest scores and the GEFT scores. The analyses indicated that inappropriate use of visuals (animation, stills) could hinder FI students from learning. Therefore, implication and recommendation are made for quality education.

Keywords: **Animation, Concept Learning, Media ZPD Model, GEFT**

1 Introduction

1.1 Background and Literature

As computer technology has advanced, so have the techniques for making animation. In recent years, animation, as a necessary component, has been widely incorporated into various media formats, such as video, CD-ROM, and web-based instructional (WBI) materials. To ensure the quality of this component, fundamental research on the effectiveness of motion images is needed. Therefore, the purpose of this study is to investigate the effectiveness of animation, through different visual presentations (Animated-visuals, Static-visuals, and No-visuals.), as a tool for concept learning.

To cope with technology, Okolo and Hayes (1996) indicated the impact of animation in CD-ROM Books on students' reading behaviors and comprehension. [9] Chanlin and Chan (1996) found the importance of using computer graphics and metaphorical elaboration for learning science concepts. [1] Large, et al. (1995), approaching multimedia and comprehension from the relationship among text, animation and captions, [6] basically reflected Mayer and Anderson's (1991, 1992) findings in which verbal description (given before the animation), pictures and words were most effective when they occurred contiguously in time and space. [7] [8] Rieber's (1994, 1996a, 1996b) findings in a series of studies basically supported the use of animation, from which valuable implications from dual-coding perspective are made. [15] [16] [17] In observing multimedia learning, concerning differences in cognitive processes, Gerlic and Jausovec (1999) found that gifted students displays less mental activity during all three formats (video, picture, and text) of presentation. [3] Park (1998) extended Park and Gittelman's (1992) early study on the selective use of animation [12] and found that the use of visual displays and contextual presentations in computer-based instruction should be based on the learning requirements of the task and expected roles of the strategy in the learning. [13] These findings have become important literature in animation study.

1.2 Theoretical Framework

Animation is made to help learners build mental images when learners receive audio and visual signs. Therefore, educators intend to strenghen learning through the use of animation. However, psychologists have diverse viewpoints toward the function of media and mental images. Piaget (1969) held that "mental images . . . generally speaking, delayed translation of the subjects' preoperatory or operatory level of comprehension. The image is far from sufficient to give rise to operatory structurations. At the very most, the image, when it is sufficiently adequate . . . can serve to refine the subjects' awareness of states which the operation will later connect by means of reversible transformations. (p. 79) [14]

On the other hand, Vygotsky saw the positive use of signs. To explain Vygotsky's notion, Van der Veer & Valsiner (1991) stated that "The mnemotechnical and other aids used by human beings to improve their performance have the character of signs, Vygotsky claimed. They are social artifacts designed to master and thereby improve our natural psychological processes. As examples of signs he lists words, numbers, mnemotechnical devices, algebraic symbols, works of art, writing systems, schemata, diagrams, maps, blueprints, etc. (Vygotsky, 1930aa/1982, p. 103). From this list it is obvious that any stimulus that can signify another stimulus may be seen and used as a psychological instrument or sign. This was indeed Vygotsky's point of view." (p. 219) [18]

The primary difference between the two thinkers concerning cognitive learning rests upon the priority of developing a mental infrastructure. Panofsky, John-Steiner, and Blackwell (1990) pointed out that for Piaget, the development of mental structures precedes the learning of logically or systematically organized concepts, whereas for Vygotsky, the learning of systematic concepts precedes the development of an elaborated logical structure. (p. 253) [11]

According to Vygotsky (1978), the "Zone of Proximal Development" (ZPD) is "the distance between the actual development level as determined by independent problem solving and the level of potential development as determined through problem solving under adult guidance or in collaboration with more capable peers." (p. 86) He also elaborated the important elements concerning cognitive learning--scientific concepts and spontaneous concepts. For learning, the two kinds of concepts in the ZPD are functioning as two magnetic forces ready to meet. Once these two kinds of concepts meet with each other, new knowledge will hence be generated. [20]

Vygotsky's theory can be adopted not only in cognitive development but also mediated learning. In such a scaffolding system as ZPD, learners can receive assistance through the use of media. For instance, the scientific concept is compared to a gateway in the ZPD, leading to the acquisition of a new concept or knowledge. Consequently, there must be a medium, functioning as a tool to bring in the messages for concept formation. According to Vygotsky (1986), "once the child has achieved consciousness and control in one kind of concept, all of the previously formed concepts are reconstructed accordingly." (p. 192) [21]

To picture the role of media related to concept formation, the researcher developed the "Media ZPD Model", in which cognitive process through the use of animation is illustrated. This model is a conceptual framework developed primarily on the basis of Vygotsky's (1986) notion of Concept Formation. [21] It also adopts, Paivio's (1986) theory of Dual Coding [10] and Gibson's (1994) notion of Visual Motion. [4] In the model, instructional media (in both realistic and symbolic representation) are carrying messages into learners' Zone of Proximal Development in different kinds of modes (verbal or nonverbal, auditory or visual, static or dynamic, and so forth). The messages, functioning as learning cues, triggers scientific concepts (the learning objectives at potential developmental level) and act on spontaneous concepts (the learners' prior knowledge at actual developmental level). Consequently, during the up-and-down interactive processes, new concepts can be formed (see Figure 1).

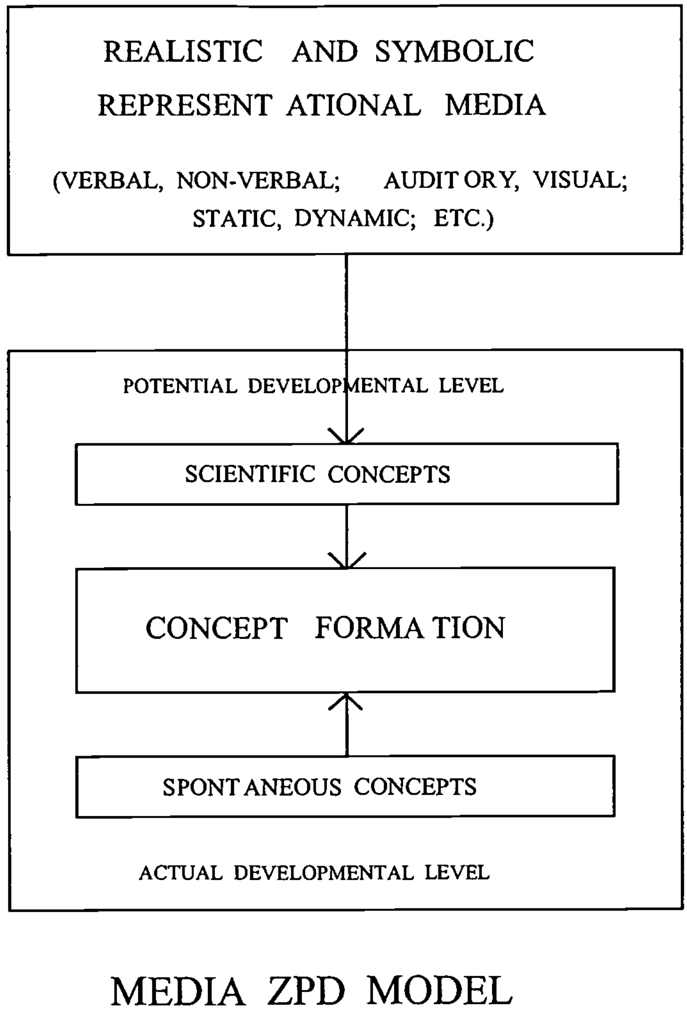

Figure 1: The Media ZPD Model.

2 Method

The design includes two independent variables: Presentation Method (PM) and Audio Mode (AM). Within the Presentation Method, there are three levels: Animated-visuals, Static-visuals, and No-visuals. Within the Audio Mode, there are two levels: Audio and Silent. Therefore, combining the two independent variables yields six different treatments. Through randomization, the subjects were assigned to one of the six treatment groups. The Silent group with No-visuals treatment served as the control group. The subjects who participated in this study were from elementary schools in the urban and suburban areas of Columbus, Ohio, in the Spring Quarter, 1996. One hundred and forty-four 5th-grade students were observed in an experiment.

3 Procedures

Before the experiment, the Group Embedded Figures Test (GEFT) was given (Witkin, Oltman, Raskin, & Karp, 1971) to measure subjects' perspective tendency. [19] Scores on the GEFT were used as the covariate to control for variability, which could not be controlled experimentally. In the experiment, variations of a 1-minute video segment (playing twice), "Cube," that displayed the concept of the relationship of the volume of a cube to its edge, were employed for the visual presentations. Visuals and audio were presented in six different ways for the six treatment groups as described above. After presenting the treatment for each group, a posttest was administered. Scores on the posttest were used as the dependent variable.

4 Data Analysis

Content experts first secured Posttest's validity. Its internal consistency reliability coefficient reported by the Test and Questionnaire Analysis System was .72. The statistics for the Posttest (Mean=7.43; STD=2.38) and the GEFT (Mean=4.98; STD=3.95) were calculated. Before testing the hypotheses, a trend analysis was conducted to test whether or not this set of data could be described in a "straight line" (Keppel, 1991, p. 144). [5] Hence, an ANCOVA procedure was conducted to do this preliminary analysis. The statistical analysis indicated that no effect of quadratic term (GEFT*GEFT) was significant, $F(1, 139) = 0.04$, $p = .84$. This procedure ensured the appropriateness of using the General Linear Model (GLM) in data analysis.

4.1 Hypothesis Testing

There are four hypotheses in the study. An overall ANCOVA procedure first tested the null hypotheses concerning the differences among each level of the two independent variables: the Presentation Method (Ho 1) and the Audio Mode (Ho 2). Also, this ANCOVA procedure detected the null hypothesis concerning the existence of interaction (Ho 3).Then, a Correlation Analysis examined the null hypotheses concerning the relationship (Ho 4) between the GEFT scores and the posttest scores.

For Ho 1, the analysis shows: $F(2, 132) = 5.88$, $p = .0036$. Since there is an interaction between the GEFT and the PM, the impacts of the Presentation Method will be discussed in the analysis of the interaction. For Ho 2, the analysis shows that a significant difference does not exist between the two audio modes, $F(1, 139) = 0.72$, $p > .05$. Therefore, this study fails to reject the Null Hypothesis 2. For Ho 3, the analysis shows that the interaction between the GEFT and the PM (GEFT*PM) is significant, $F(2, 132) = 3.72$, $p < .05$. The analysis indicates that there is an interaction between the GEFT and the PM. Therefore, this study rejects the Null Hypothesis 3. For Ho 4, the analysis shows that Pearson coefficient of correlation is significant ($r = .37$, $p < .001$). Therefore, this study rejects the Null Hypothesis 4. This analysis indicates that there is a "positive and moderate" relationship between the scores measured by the GEFT and the scores measured by the posttest for those learners who receive the mediated instruction.

4.2 Examining the Interaction

An ANCOVA, solely focused on PM, GEFT, and GEFT*PM, was conducted, to examine the interaction. In **Table 1**, the analysis for the Presentation Method is reported as follows: $F(2, 138) = 5.75$, $p = .004$. In **Figure 2**, a three-lined disordinal interaction is found. The three lines in the interaction chart represent (1) Animation, (2) Still-visuals, and (3) No-visuals, respectively.

Table 1: ANCOVA Summary Table for the Posttest as a Function of the Presentation Method and the Group Embedded Figures Test: Examining the Interaction.

SOURCE	*SS*	*df*	*MS*	*F*	
PM	51.7671	2	25.8835	5.75	** (a)
GEFT	122.7265	1	122.7265	27.28	***
GEFT*PM	34.8828	2	17.4414	3.88	* (b)
ERROR	620.9322	138	4.4995		
TOTAL	805.3055	143			

Note: *p <.05, **p <.01, ***p <.001, " * "=Interaction, (a)Omega-Squared=.053
PM=Presentation Method, GEFT=Group Embedded Figures Test, (b)Omega-Squared=.032

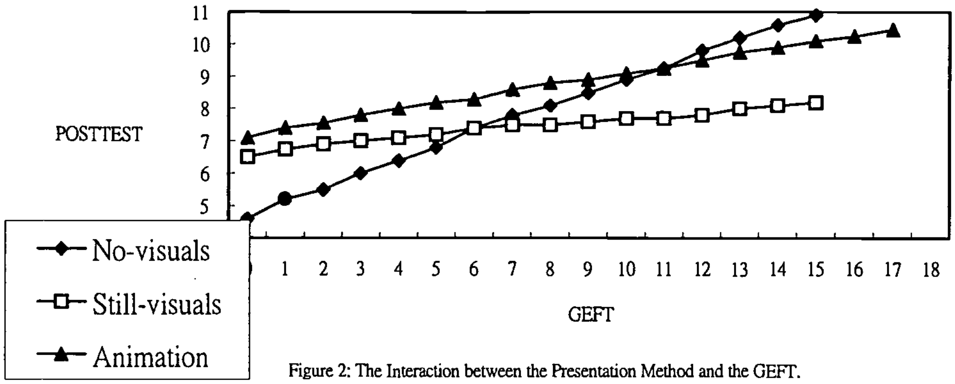

Figure 2: The Interaction between the Presentation Method and the GEFT.

4.3 Separating the GEFT Scale into Two Categories

The scale of the GEFT scores was separated at the point "5," an integer representing the GEFT Mean score (4.9), into two categories: GEFTCAT1 and GEFTCAT2. Subjects whose scores are lower than and equal to 5 (0 - 5) in the GEFT scale belong to the GEFTCAT1. Subjects whose scores are higher than 5 (6 - 18) in the GEFT scale belong to the GEFTCAT2. Then, the data in each category were analyzed separately without the influence of the interaction effect.

4.4 Analyzing the Simple Effects of the Presentation Method

A. Simple Effects in Category One

In Category One (GEFTCAT1), the analysis shows that significant differences do exist among the three presentation methods, $F(2, 86) = 5.23, p < .01$. Therefore, this study rejects the Null Hypothesis 1 in GEFT Category One. Then, three planned pairwise comparisons were conducted to analyze the differences among the three levels of the PM. The results are reported as follows: (1) The first comparison "Contrast PM1 vs 2" shows that PM1 is not significantly different from PM2, $F(1, 86) = 1.09, p > .05$. (2) The second comparison "Contrast PM 1 vs 3" shows that PM1 is significantly different from PM3, $F(1, 86) = 10.18, p < .01$. (3) The third comparison "Contrast PM2 vs 3" shows that PM2 is significantly different from PM3, $F(1, 86) = 4.56, p < .05$. The analysis indicated that both Animation and Still-visuals are useful presentation methods in comparison to no visual presentation at all. Hence, the analysis in GEFT Category One supports the use of visuals in the mediated instruction. The results for the GEFTCAT1 are reported in Table 2 and Figure 3.

B. Simple Effects in Category Two

In Category Two (GEFTCAT2), the analysis shows that no significant difference exists among the three presentation methods, $F(2, 50) = 1.93, p > .05$. Therefore, this study fails to reject the Null Hypothesis 1 in GEFT Category Two.

Table 2: ANCOVA Summary Table for the Posttest as a Function of the Presentation Method and the Group Embedded Figures Test: In the GEFTCAT1.

SOURCE	*SS*	*df*	*MS*	*F*	
PM	44.1472	2	22.0736	5.23	** (a)
GEFT	35.7909	1	35.7909	8.48	**
PM 1 VS 2	4.5863	1	4.5863	1.09	
PM 1 VS 3	42.9463	1	42.9463	10.18	**
PM 2 VS 3	19.2621	1	19.2621	4.56	*
ERROR	362.8846	86	4.2195		
TOTAL	431.6000	89			

Note: $*p<.05, **p<.01$, (a)Omega-Squared=.082, PM1=Animation, PM2=Still-visuals, PM3=No-visuals

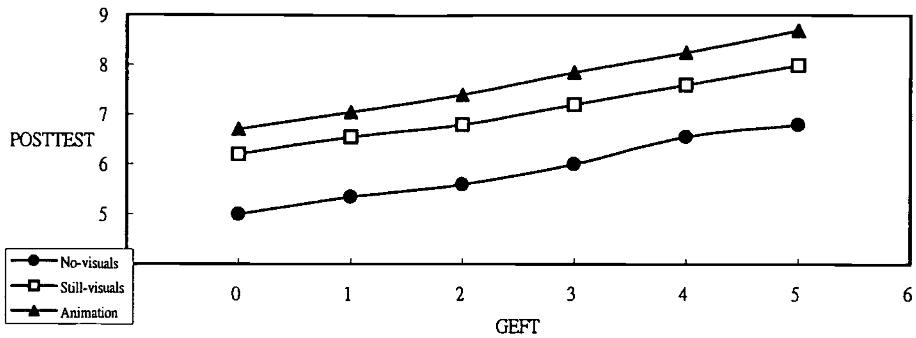

Figure 3: the Simple Effects of the Presentation Method in the GEFTCAT1 (When Interaction Effect Is Removed).

5 Conclusions

For most 5th-graders, namely the Field-dependent (FD) learners in this study, animation can be used as a useful visual tool for concept learning as noted in the Media ZPD Model. For Field-independent (FI) learners, different ways of presenting visuals have no significant differences. The picture in the **Figure 2** even reveals that the performance of the No-visuals group is slightly over the performance of Animation group and Still-visuals group. In other words, the interaction between learners' field-dependent tendency and presentation methods implied that inappropriate use of visuals (animation and still images) could hinder FI students from learning. Hence, these findings provide meaningful insight for schoolteachers, instructional designers, and media producers.

This study found that there is a positive and moderate relationship between the GEFT scores and the posttest scores. That is, learners' prior knowledge of disembedding hidden figures is associated with their performance in visual learning. Based on Vygotsky's notion, students' ability for visual learning may function as a basic (spontaneous) concept in the *Zone of Proximal Development*. This ability is interrelating with a new (scientific) concept introduced (see **Figure 1**). "As they meld . . . scientific concepts come to life and find a broad range of applications" (Daniels, 1996, p. 11). [2] Then, learning occurs. Therefore, this study infers that improving students' basic visual skills can lead to better performance in learning new concepts.

Since animation is widely used in video, CD-ROM, and web-based instruction (WBI) materials, how concepts are formed through the aid of moving images deserves educators' great concern. Therefore, it is recommended that educators help students improve visual learning ability as a fundamental skill. Also, for FI students, advise in individual learning becomes necessary. In the experiment, animation viewing was conducted under such circumstances: (1) no activities were provided by teachers; (2) animation could be too short (1 minute, playing twice); and (3) no texts and illustration were used, etc. Yet, such circumstances are quite similar to the current WBI learning situations: namely, students usually navigate in WWW without guidance, students' attention is sometimes distracted by fancy animated images, students often ignore texts when visiting WBI sites, etc. Hence, to avoid such drawbacks when using animation, media designers need to (1) arrange appropriate activities, (2) reduce unnecessary distraction, and (3) use suitable texts. Schoolteachers and instructional designers should be able to assist them to accomplish these. In future studies, approaches will focus on the design of instructional activities when animation is employed. Nevertheless, this study was conducted with an expectation--to increase understanding of the use of animation for quality education.

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