What should we do with pre-instructional conceptual frameworks?: A suggestion for instructional strategy

Hee-Ok Jung

(Seoul National Univercity)

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Introduction

Why is it very difficult for most students to learn some scientific concepts? Reseachers attribute these difficulties to abstractness of the material, sophistication in the type of reasoning required, and lack of mathematical skills(eg., Arons, 1976 ; Hudson and McIntire, 1977 ; Champagne and Klopfer, 1980). During the last 15 years or so many resarchers have focussed on students' pre-instructional conceptual frameworks as a main source of student's failure in understanding of scientific concepts. The conceptual framework implies a set of beliefs or expectations about a system. When students come to a science class with a conceptual framework developed from their everyday experiences, the expository presentation of scientific concepts is unlikely succeed in changing students' conceptual framework toward the scientific concepts held by scientists. The scientist's concepts are easily misperceived or distorted by students so as to fit their existing framework, or they may be memorized separately as fomulae with little connection to the fundamental qualitative concepts.

Since 1970's many researchers(McDermott, 1984 ; Whith 1988 ; Trowbridge, 1979 and etc.) have examined the characteristics of pre-instructional conceptual frameworks in many subject areas such as mechanics, electromagnetism, thermal physics, and etc., However, there has been few studies on how to change students' pre-instructional conceptual framework toward the scientists' framework.

Based on the studies on the characteristics of students' pre-instructional conceptual framework several researchers(Viennot, 1979 ; Gunstone, 1981 ; Minstrell, 1982 ; and Takikawa, 1988) pointed out that teaching a scientist's framework will only be effective when students are led to look at the discrepancies between their concepts and the scientists' framework. An instructional strategy have been developed in this study and tried out to change students' pre-instructional conceptual frameworks toward the scientists' frameworks. The steps involved in the instructional strategy are :

1) Using a simple qualitative quiz teachers make students acknowledge or articulate their pre-instructional conceptual frameworks before the presentation of scientists' framework on the subject.

2) Students perform some experiments which can reveal the scientists' conceptual framework.

3) Students compare their pre-instructional conceptual framework and the results of the experiment and realize that the scientists' conceptual framework can explain the result of the experiment better than their pre-instructional conceptual framework.

An important aspect of the instructional strategy is that students must realize the discrepancy between their pre-instructional conceptual framework and the results of the experiment. Then, What sort of reasoning is involved in this instructional strategy? Let us consider the most prevalent pre-instrutional conceptual framework in the area of force and motion. When a student says that a constant force results in a constant velocity this statement can be interpretted as an hypothesis.

According to a series of studies by Lawson(1983, 1984a, 1984b) most adults use a biconditional(if only if) interpretation when they test a hypothesis. In other words, given the hypothesis that p causes q($p \cdot q$) most adults expect($p \cdot q$) and ($\dot{p} \cdot \dot{q}$) would occur. Also they do not expect($\dot{p} \cdot q$) or ($p \cdot \dot{q}$) would occur. Such an expectation is quite correct when p is the only possible cause of q. Hypothesis testing reasoning begins with the biconditional reasoning(if, only if). Even though more complex reasoning involving notions of probability and the control of variables are needed when p is just one among many possible causes of q, in reality, the logic actually employed during the knowledge generating process is the biconditional, that is, the hypothesis is assumed in the form of "p only p implies q". Then the comparison of the prediction and the observation can be used to verify the hypothesis in a probablistic sense.

Lawson has reported that students' biconditional reasoning increases gradually with age. His research on the role of biconditional reasoning also indicates that it is acquired during early adolescence by many individuals and is a precondition for formal operation. If a student is to benefit from the instructional strategy described above, the student must have at least the biconditional reasoning ability. The students who do not have biconditional reasoning can not look at the discrepancy between their pre-instructional conceptual framework and the scientists' framework because they do not know what to expect given the hypothesis. Futhermore, the instructional strategy may cause confusion to some students without the biconditional reasoning by letting them articulate their own pre-instructional conceptual frameworks.

Purposes of the study

This study was designed to investigate the effect of the instructional strategy which lead students to look at the discrepancies between their pre-instructional conceptual framework and the scientists' framework. Also the interaction effect of the biconditional reasoning and the instructional strategy was examined.

Methods

Subjects; The participants in this study included 135 female 11th grade high school students and 124 male 10th grade high school students. The subjects were from two high schools(one for female, the other for male) located in the central part of Seoul.

Instructors ; Two teachers, one with one year of teaching experience and the other with about 15 years of teaching exprience guided the classes during two hour instruction on Newton's second law. Newton's second law was chosen because the topic has been substantially studied by many researchers in many different countries. The striking similarities in the characteristics of the students' pre-instructional conceptual frameworks across different cultures have been well established.

Instruments

Pre-instructional quiz : A simple qualitative quiz on the relationship between force and motion was asked to the students in the experimental groups.

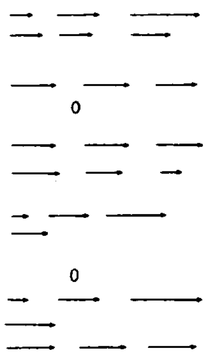
Biconditional reasoning test : Eight items on biconditional reasoning developed by Lawson were administered to all subjects.

Posttest on Newton's second law : Thirteen items on the relationship between the force, velocity, and acceleration were included in the post test. Of these six items deal with situations similar to that shown in the pre-instructional quiz. The situations in the rest of the items were new to students.

Procedures

Two different instructional guides were written for the teachers, instructional guide A for the experimental groups and instructional guide B for the control groups. The main difference between the two instructional guides was on the use of students' pre-instructional conceptual frameworks. In the experimental groups, the teachers spend 5-10 minutes to identify the students' pre-instructional conceptual frameworks using the simple qualitative quiz. The students' pre-instructional conceptual frameworks then were compared with the scientists' view after the students performed an experiment on Newton's second law. In contrast, the control groups were not given the pre-instructional quiz. Therefore, the students' pre-instructional conceptual frameworks were not identified and compared with the scientists' view.

Experimental groups. The teachers explained that the class would study the motion of an object under a constant force and the students were given two questions to answers. They were : What forces are acting on an object (1) accelerating at a constant rate? (2) moving at a constant velocity. The positions of a cart on a frictionless ice field are shown at certain time intervals for each question.(see Fig 1.). It took about five minutes for the students to answer the questions. While the students were drawing their answer using arrows representing the forces, the teachers walked around looking at the students' responses. Then, they drew several typical answers on the blackboard. When all the students finished the quiz, the teachers asked if there were any answers not included in the types on the blackboard. One or more types were added to those already on the blackboard. Six types of answers and the number of the students responding with each type of answer are shown in Table 1. Over half the subjects raised their hand in agreement with the following answer ; the force grows bigger at a constant rate for question (1) and the forces remain constant for question (2) This reveals the well established students' naive belief about the relationship between motion and force. A question on whether the cart starts from the starting point A was raised by both male and female subjects. The teachers explained that the cart was at rest at point A for question (1) and was moving continuously for question (2) The classes were told the results of the quiz by the teachers ; more than half of the students believed a constant force resulted in a constant velocity, and a force increasing at a constant rate resulted in accelerating motion at a constant rate



Group	Force	Boys	Girls
A		38	34
B		3	6
C		3	9
D		5	8
E		6	2
F		2	2

〈Table 1〉 Frequency of number of students in various groups for pre-instructional quiz

The teachers then asked how the subjects would find out the correct answer for the questions ; then, they led the students to an experiment in which the students could find which answer on the blackboard was right. The teachers asked for examples of the motions of an object under a constant force. In the girls class, a student answered, "free falling". The teacher asked why things fall down. Many students answered, "Because the earth pulls then down." The teacher continued his questioning : "When this piece of chalk is falling down toward the earth, is the force acting on the chalk the same way until it touches the ground?" Most students answered, "yes." The teacher asked one of the students who said "no" why she thought so. She answered that the force acting on the piece of chalk depends on the distance between the piece of chalk and the earth. The teacher explained that the weight of the chalk one meter above the ground and two meter above the ground would not differ much. He also explained that the difference in the gravitational acceleration between the two points is so small that the force acting on the chalk can be considered to be constant within short distance from the earth.

In the boy's class, a student answered that a constant force was applied to a car when a person presses the accelerator with a constant pressure, so that the car runs at a constant speed. Another student said the earth is under a constant speed. Another student said the earth is under a constant force so that it revolves around the sun at a constant speed. One student also said it would be possible to apply a constant force using a spring balance.

Then the teachers showed how a constant force can be applied to a mechanical cart using a pulley and an object in free fall. Finally, the teachers explained how to use the time recorder. For the experiment, the students measured the distance between the points on the paper tape and calculated the differences between the adjacent distances. The students plotted the distances and the distance differences for adjacent intervals, then calculated the velocity and the acceleration from the results of the experiment. The time interval between the points on the paper tapes was used as one unit of time.

After the experiment, the teachers discussed the results of the experiment with the classes. Then the teachers asked what was the correct answer for the pre-instructional quiz. Almost all the students raised their hand for the correct answer ; a constant force for the accelerating cart. Then the teachers asked when would an object move at a constant velocity. Several students answered that an object would move at a constant velocity. The teachers explained that an object moved at a constant velocity when there was no net force acting on the object but accelerated at a constant rate under a constant force.

Control group ; As the pre-instructional quiz was not included. a comparison between the students' answers to the quiz and the results of the experiment was not made. Otherwise. the two class activities were the same. Since about 5-10 minutes was spent for the quiz the teachers spent more time explaining the differneces between motion under no net force and motion under a constant force.

Results and Discussion

Two weeks after the experiment a posttest on Newton's first and second law was given to the subjects in both the experimental and control groups. A biconditional reasoning test of eight items was administered at the same time as the posttest. The posttest included two types of question ; one directly related to the situation shown in the pre-instructional quiz. the other in the situations new to the students. Before the posttest was analyzed the number of students in the experimental and control groups who possessed biconditional reasoning ability was determined. See Table 2 for the number of students in the different groups. The female subjects showed slightly higher percentage in biconditional reasoning ability than the male subjects. This was not surprising because the female subjects had one more year of high school eduaction and were approximately one year older than their male counterparts. Chi-square tests were run to find out if there was any differences in biconditional reasoning ability between the control and experimental groups. Separate tests were performed for the male and female subjects due to the differences in their educational experiences and ages as well as the teachers who guided the instruction. The Chi-square test showed no significant differences for either male or female subjects between the control and experimental groups. The value of the Che-square was 0.39 for boys and 0.31 for girls.

		Boys		Girls	
		Exp.	Contrlo	Exp.	Control
Biconditional reasoning ability	with	32	28	34	32
	without	26	29	25	29

〈Table 2〉 Number of students in experimental and control groups with biconditional reasoning ability

The results of the posttest were analyzed by randomized block design. The direct and applied questions were analyzed saparately. Table 3 shows the results of the analysis. Each question was counted as one point. For direct questions. both the male and female subjects in the experimental groups, in which the students' pre-instructional conceptual frameworks were identified and compared with the scientists' standard view. did significantly better than those in the control groups. For applied auestions. the effect of the use of pre-instructional conceptual frameworks was not significant for either male or female subjects.

Source	DF	SS	MS	F
		Direct Questions		
		Boys		
A	1	9.1	9.1	5.2*
B	1	23.8	23.8	13.7**
AXB	1	1.8	1.8	1.0
Error	111			
Total	114			
		Girls		
A	1	7.1	7.1	4.5*
B	1	9.6	9.6	6.2**
AXB	1	0.1	0.1	<<1
Error	116	181.8	1.6	

Total	119			
		Applied Questions		
		Boys		
A	1	0.3	0.3	<<1
B	1	24.1	24.1	9.9*
AXB	1	0.5	0.5	<<1
Error	111	271.1	2.44	
Total	114			
		Girls		
A	1	3.6	3.6	1.4
B	1	13.3	13.3	5.13*
AXB	1	6.5	6.5	2.5
Error	116	301.1	2.6	
Total	119			

A: Use of pre-instructional conceptual framework
B: Biconditional reasoning ability
*p <0.05
**p <0.025

〈Table 3〉 Summary table of the results of post-test

Although the differences between the experimental groups and the control groups were not significant at 0.05 level, the female subjects with biconditional reasoning ability in the experimental groups. See Table 4. On the other hand, there was almost no difference in the means of male subjects between the experimental groups and the control groups regardless of the presence of biconditional reasoning ability. That is, biconditional reasoning ability does not have any significant interaction effect with the use of pre-instructional conceptual framework in the male subjects. Both male and female subjects who had biconditional reasoning ability did significantly better on both direct and applied question than thier counterparts who did not have biconditional reasoning ability.

Direct				
	girls		boys	
	Exp	Control	Exp	Control
BCR yes	5.0	4.6	4.8	4.0
BCR no	4.5	4.2	3.5	3.2

Applied				
	girls		boys	
	Exp	Control	Exp	Control
BCR yes	4.6	3.9	3.5	3.3
BCR no	3.5	3.7	3.6	2.2

〈Table 4〉 Means of postest

To sum up, students benefited from the instruction that used the students' pre-instructional conceptual frameworks to invoke the students' awareness on the differences between their own conceptual frameworks and the standard scientists' view. In situations similar to those used in the class pre-instructional quiz, the students in the experimental groups did significantly better than those in the control groups. However, the transfer of the understanding of the concepts did not occur when students were faced with situations defferent from those presented in the pre-instructional quiz. This result is not surprising because it has been found by many researchers that students' ways of explaining the same scientific phenomenon varies with the context of the questions. To prove the effectiveness of the use of pre-instructional conceptual frameworks through different situations, a long therm experiment, where students can be exposed to many situations dealing with the same scientific concept, is necessary. While doing this, students should be pointed out the similarities between the familiar situation and new situations which they face for the first time.

The author expected the students who had biconditional reasoning ability would benefit more from the instructional method than students who did not. It seems to the author that students in the experimental groups were able to do better than those in the control groups regardless of their biconditional reasoning ability on the direct questions partly because they were exposed to the quiz questions similar to the direct questions. However, it is worthwile to use students' pre-instructional conceptual frameworks if students can retain what they have learned by spending 5-10 minutes for pre-instructional quiz.

For the applied questions, the results of the female subjects showed a slight interaction effect which the author expected, although the effect was not significant oat 0.05 level. The differences in the test results between the male and female subjects seem to have come from the differences in the two teachers. The teacher who guided the female subjects has a fifteen year experience in teaching physics and had noticed the effect of pre-instructional conceptual frameworks on instruction for a long time. Even though he has not done any systematic research in this area, he has tried several methods to change students' pre-instructional conceptual frameworks toward the scientists' standard view. This indicates that how teachers perceive the impacts of pre-instructional conceptual frameworks is very important in using the method employed by the experimental groups in this study.

Educational implications and suggestions for further studies

It is suggested that teachers should find out what kinds of ideas their students bring into science class to change their pre-instructional conceptual frameworks towad standard scientists' view. Qualitative or semi-quantitative questions on basic concepts appear to be a good methods to draw out students' pre-instructional conceptual frameworks. Once pre-instructional conceptual frameworks are diagnosed, instruction should be designed to lead students to look at the discrepancies between what they believed before instruction and the standard scientists' view.

As emphasized in the "introduction" section, teaching a concept becomes very difficult when students have already formed their own conceptual framework in that area. Thus, teacher education should stress the importance of teachers' questioning and listening to their students. The most important thing in changing students' pre-instructional conceptual framework toward the scientists' standard view is to know their students'--know what and how their students think. To find out what their students think about a scientific phenomenon, teachers must probe into their students' reasonings by using well organized questions. A Norwegian study(Sjoberg, 1981) shows that some of the conceptual difficulties found in this study are nearly as prevalent among future secondary school teachers as among students. Therefore, the importance of the subject matter should not be neglected in teacher education.

Since substantial information on how to diagnose student conceptual frameworks and how to use the conceptual frameworks to shift the students' view toward standard science can be obatained mostly by teachers in real calssroom activities, teachers should be given more opportunities to exchange their information about student thinking. Also they should be encouraged to be involved in research activities on studets' framewouks.

The content area in this study was restrcted to mechanics. Research on alternative conceptual framoworks of subjects areas other than physics, will be valuable in helping teachers to improve the instructional methods and to develop curriculum material that take into account the students' pre-instructional conceptual frameworks. The effect of the instructioanl method, in which students' pre-instructional conceptual frameworks are identified by simple qualitative quizes designed to lead students to look at the discrepancies between their frameworks and the scientists' standard view.

should be examined in a long term experiment. Even though any significant interaction effet between use of student' pre-instructional conceptual frameworks and biconditional reasoning was not found in this study, it would be worth investigating the interaction effect of the two variables when the instructioanl method is used with younger strdents.

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Figrue Caption

요 약

수업전 개념구조를 고려한 수업방법에 관한 연구

정 희 옥
(서울대학교)

어떤 현상에 대한 학생들의 수업전 개념구조가 과학자들의 그것과 다를때 이 수업전개념을 간단한 정성적인 퀴즈를 통하여 학생 스스로 인식하게 하고 실험 또는 관찰을 통하여 학생 자신의 수업전개념 보다는 과학자들의 개념이 실험결과를 더 잘 설명할 수 있다는 것을 깨닫게 함으로써 학생들의 수업전 개념구조를 변화시키려는 교수모델을 고안하여 그 효과를 검토하였다. 고등학교 1학년 남학생 115명(실험집단 58명, 비교집단 57명)과 고등학교 2학년 여학생 120명(실험집단 59명, 비교집단 61명)을 대상으로 뉴우턴 제2법칙에 대한 학습에 적용하고 2주후에 뉴우턴 제2법칙에 관한 시험(13문항)을 실시하였다. 그 결과, 퀴즈에 사용한 것과 유사한 상황을 다룬 문제에서는 실험집단의 성적이 비교집단의 성적보다 유의하게 높았다. 그러나, 같은 개념을 다루나 새로운 상황의 문제에서는 그 효과가 유의한 차이를 나타내지 않았다. 한가지 개념이 여러가지 새로운 상황속에 나타날때 학생들에게 이미 친숙한 상황과 새로운 상황 사이의 유사점을 강조하며 위의 교수법을 계속하여 사용한다면 학생들의 뿌리깊이 밝힌 수업전 개념구조를 변화시킬 수 있으리라 사료된다.

위의 교수법은 학생들이 자신의 수업전 개념구조를 명확히 인식하고 그 불합리함을 깨달아야 하므로 자신의 수업전 개념구조에 근거하여 어떤 결과를 예측할 수 있는 예측논리(Expectation or biconditional Reasoning)가 형성된 이후의 학생들에게만 효과가 있으리라 가정하였으나 교수방법과 예측논리 사이에 유의한 상호작용효과(interaction offect)는 나타나지 않았다. 다만 여학생의 경우에서만 학생들에게 새로운 상황의 문제에서도 예측논리를 이미 형성한 실험집단의 평균이 이에 상응하는 비교집단의 평균보다 높았다. 이것은 남학생과 여학생을 지도한 교사의 교수경력과 학생들의 수업전 개념구조에 대한 교사의 인식정도에 큰 차이가 있었음을 고려할 때, 위의 수업방법을 사용하는 데 있어 교사가 학생들의 수업전 개념구조가 학생들의 개념획득에 얼마나 커다란 영향을 끼치는가에 대해 인식하는 것이 중요한 요인임을 시사한다.