Measurement of the conceptual change produced in pre-school and elementary teachers based on MECIBA training methodology

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Abstract

In this work we intend to measure the conceptual change produced in a group post-graduate program called "MECIBA" (*Mejoramiento de las Ciencias en la Enseñanza Básica / Improving Science in Elementary Teaching)*, whose goal it is to enhance the quality of science teaching. To achieve this goal we designed and applied tests and interviews aimed to know more about the pre-conceptions that the participants had in two areas of Physics that were covered during the workshops: "Moving Objects" and "Nature of Light". With the results obtained on the pre and post tests, and the interviews made before each workshop to increase our knowledge of the preconceptions of the participants, we could observe an important improvement on the replacement of the preconceptions by formal conceptions, and also in the capacity to apply them to different situations, all of which are exposed through quantitative data.

Key words: Conceptual Change, Preconceptions in Physics, Teacher Training.

Resumen

En este trabajo pretendemos medir el cambio conceptual producido en un grupo de profesores de educación básica y prebásica como fruto de su participación en un programa de post título que busca elevar la calidad de la docencia en ciencias, *"MECIBA" (Mejoramiento de las Ciencias en la Enseñanza Básica).* Para lograr nuestro objetivo diseñamos y aplicamos entrevistas y tests dirigidos a conocer las preconcepciones que los participantes poseían respecto a dos áreas de la Física a tratar en los talleres: "Movimiento de los objetos" y "Naturaleza de la luz". A partir de los resultados obtenidos en los pre y post-tests, así como también en las entrevistas realizadas antes de cada taller, para ampliar nuestro conocimiento sobre los preconceptos de los participantes, pudimos apreciar un gran avance en el reemplazo de preconcepciones por concepciones formales, así como también en la capacidad de aplicarlas a distintas situaciones, lo cual queda expuesto a través de datos cuantitativos.

Palabras clave: Cambio conceptual, Preconcepciones en Física, Formación de profesores.

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I. INTRODUCCIÓN

Just a few years ago in our country, the teaching of science in elementary and middle schools was reduced to the development of subjects that mainly belonged to Biology. This is a result of the fact that almost all programs of elementary and pre-school teaching preparation only have Biology courses, and teachers do not receive preparation in Physics and Chemistry.

Nevertheless, since 1996 the Educational Reform that has been put into practice in our country includes a new curriculum that includes specific contents of Physics and Chemistry, which, according to the information gathered, cannot be implemented because elementary and middle school teachers are not sufficiently prepared to do so. In general terms, they do not have a good management of the content that must be taught and need to update their didactics to teach science from an inquiry-based approach. It is necessary to face up to the challenge of improving the knowledge and methodologies used nowadays by elementary and middle school teachers in order to bring the Educational Reform to the classrooms and to Chilean students.

The MECIBA project responds to the necessity of offering professional development programs of high quality for teachers. It fosters a better student learning through the development of a curriculum that seeks to improve the capacities of the elementary and pre-school teachers to teach science. This curriculum has been modeled based on the Operation Primary Physical Sciences (OPPS) program [1], developed in the Physics and Astronomy Department of the Louisiana State University, United States of America, to prepare leader teachers who can offer training to their colleagues. The professional development between colleagues is an innovating course of action taken in Chile. The MECIBA project develops a line of investigation to examine its impact and enhance the knowledge about its characteristics for its effective use.

Within this framework, it will be determined if the above-mentioned curriculum can produce a conceptual change in the 21 participants in the program in accordance with the new demands of our Educational Reform, always considering that the knowledge that our teachers have corresponds only to preconceptions built due to the early and frequent interactions between the individual and its environment. It is for this reason that in Physics, unlike in other subject matters, we can find more preconceptions, because these are the first ones built by the individuals.

II. THEORETICAL FRAMEWORK

Nowadays, diverse constructivist models agree on different aspects: learners build meanings and do not reproduce exactly what it is taught to them; to understand something presumes the establishment of relationships with other elements; all learning depends on previous knowledge (Resnick in [2] and references therein). All these aspects point to meaningful learning and to achieve this, according to Ausubel [3], the previous ideas are crucial. When learning is meaningful, learners are able to relate the new knowledge with the one they already have, achieving a new logical, meaningful connection between them.

But, how difficult it is to change a preconception? Different researches [4, 5, 6] have shown that an important reason for the persistence of the conceptual mistakes is the fact that in the teaching-learning process the previous conceptual structures of students are not considered. The importance of using the preconceptions as a starting point is one of the most important aspects of the constructivist conception of knowledge.

This is the reason why we are basing our work on the model of conceptual change of Strike and Posner [7], which seeks a change on the assimilation (addition of new information to the previously existing schemas) and then on the accommodation (modification of the existing schemas) of the new concepts acquired, using motivation and causing a conflict between the previous ideas and the new ones. Following this model, when the subject faces a problematic situation, he or she looks for a solution on the basis of his preconceptions. The inability to find a solution results in dissatisfaction with his existing ideas. Therefore, he or she then tries to find an answer in the new acquired concepts (alternative conceptions) that turn out to be more adequate and more useful. Since scientific conceptions differ greatly from the individual's preconceptions, they cannot coexist. Otherwise, the expected conceptual change cannot be achieved.

To achieve the goal set by the above-mentioned model, the teachers participating in the MECIBA program worked on the basis of the Learning Cycle. This inquiry-based methodology is founded on the "Learning from Experience" model proposed by David Kolb [8] and on Piaget's theory ([9] and the references therein). According to Piaget, learning occurs by means of two complementary processes: the Assimilation and the Accommodation of knowledge. Individuals assimilate a new knowledge when they face it, experience it and investigate it, that is, when they try to appropriate it. Accommodation of the new knowledge takes place when they modify their preconceptions or schemas depending on that new knowledge. It is through these two processes and the corresponding adaptation of the individual that a cognitive restructuring of the learning process is achieved.

Kolb's learning model can be applied to both children and adults and it has 4 stages:

- Concrete Experience: participants confront a specific situation and try to give an explanation of the phenomenon on the basis of their preconceptions. In this stage we can infer which the erroneous preconceptions.
- Observation and Processing: in this stage the participants develop an inquiry attitude. They work in groups, executing experimental activities from which questions and ideas come up to try to explain or interpret the observed phenomenon.
- Conceptualization and Generalization: In this stage, through new experiences, new concepts or definitions, related to the activities they performed on the previous stage, are given to the participants. These activities lead the participants to question their preconceptions and a cognitive conflict occurs. Through the formulation of certain questions the participants are then guided through a reflection process to clarify their misconceptions.
- Application: Finally, participants have to face up to new activities where they have to apply the new ideas and scientific concepts acquired, clarify their difficulties and establish a firm command of the subject taught.

III. METHODOLOGY

There are many instruments used to measure alternative conceptions and the subsequent conceptual change. We have chosen to work with two kinds of strategies: interviews and tests. In both cases the general objective was to gain knowledge, from another point of view, of the participants' preconceptions and the way in which the participants applied those preconceptions in practice when confronting a given problematic situation.

• **Interviews.** Due to time constraints the interviews were applied to a sample of participating teachers, which was selected using criteria such as age, gender, teaching experience, speciality and teaching level to obtain a wide spread of teaching environments and variables. The interview included questions that addressed the beliefs held by teachers related to a specific situation. But as the interview progresses, the questions lead the teachers to a contradiction, which means that they have 2 or more answers to explain the same phenomenon; their preconceptions are in conflict.

• **Test.** Tests were designed and administered to all participants 15 days before the workshop and immediately after each workshop. In these tests the questions were selected such that participants could give coherent answers according to their preconceptions.

IV. RESULTS

The tables presented below show the number of participants and also the percentage of them that manifested in their answers the existence of each listed preconception listed.

In the "Moving Objects" unit, the test had 12 questions (see Appendix 1).

The results obtained on the pre-test showed an average of 21% of correct answers among the 21 participating teachers. The pre-test application identified the teacher's preconceptions when they first came to the workshop. Similar results have been obtained in [10] and [11] in studies of high school students' preconceptions. The most frequent preconceptions we found are shown in Table I.

TABLE I. Teacher's preconceptions in the "Moving Objects" unit according to the pretests.

Preconception	Total	%
Speed, velocity and acceleration are the same.	21	100
When 2 bodies of different masses interact with each other, the force exerted by the more massive body is greater than the force exerted by the less massive body.	15	71
In a free fall situation, the acceleration depends on the mass of the bodies.	10	47
There is no gravity in a vacuum.	5	23

The interviews on this unit (see Appendix 2) were made to 12 teachers and included 8 questions.
The results obtained reaffirmed the answers on the pre-test. Some of these answers were:

TABLE II. Teacher's preconceptions in the "Moving Objects" unit according to the interviews.

Preconception	Total	%
When throwing a ball vertically, the "force of the hand" acts on it, which disappears when the ball reaches its maximum height.	11	92
There is no gravity in a void.	9	75
Velocity is the same as acceleration.	6	50

Likewise, in the "Nature of Light" unit, an 11 question pre-test (see Appendix 3) was administered to 21 teachers, showing an average of 33 % of correct answers.

TABLE III. Teacher's preconceptions in the "Nature of light" unit, according to the pretests.

Preconception	Total	%
Inserting a plate with a little hole between a source of light (bulb) and a screen will show a spot of light that corresponds to the beam of light that goes through the hole.	13	62
When a ray of light hits a reflecting surface, the reflected ray goes in any direction.	8	38
The shadow is created because the object "cuts off" (interrupts) the rays of light coming from the source.	13	62
When a ray of light hits a reflecting surface, the reflected ray goes in any direction.	6	29
When a white and a black surface are exposed for a long time to a source of light, the black surface is more heated because it "attracts" the light, and the white surface "rejects" it.	6	29
Reflection is the same as refraction.	6	29

In the same unit a 6 question interview (see Appendix 4) was administered to 12 teachers. The most common preconceptions were:

TABLE IV. Teacher's preconceptions in the "Nature of light" unit, according to the interviews.

Preconception	Total	%
We look because we have eyes and we can see.	11	92
Light does not travel in a straight line.	6	50

The results obtained on the interviews and on the pre-tests helped us to identify the subject matter that needed to be reinforced during the workshops. The results of the post-test, applied after each workshop, showed great improvement. The averages of correct answers between the 21 participants in each unit are shown in the following chart:

TABLE V. Post-test results in each unit after MECIBA workshops.

	% Correct Answers	
Unit	**Pre-Test**	**Post-Test**
Moving Objects	21	63
Nature of Light	33	78

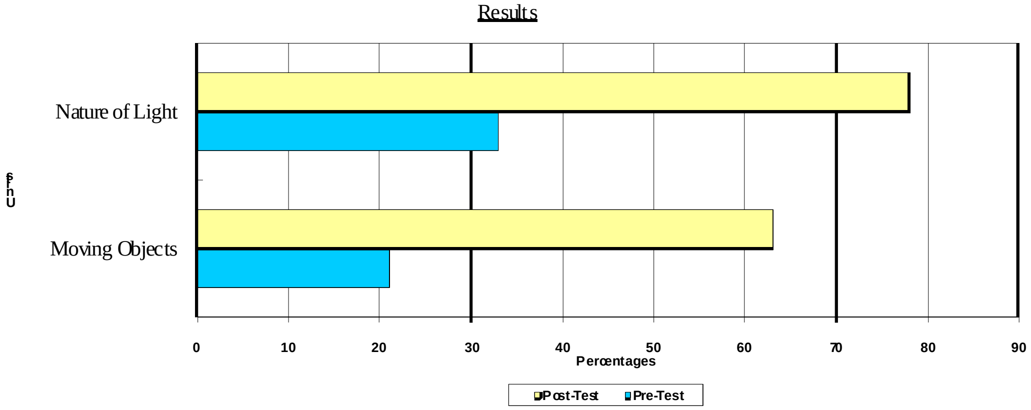

FIGURE 1. Average pre-test and post-test results in each unit.

Among the conceptual mistakes that persisted after each workshop we found:

1. Unit: "Moving Objects"

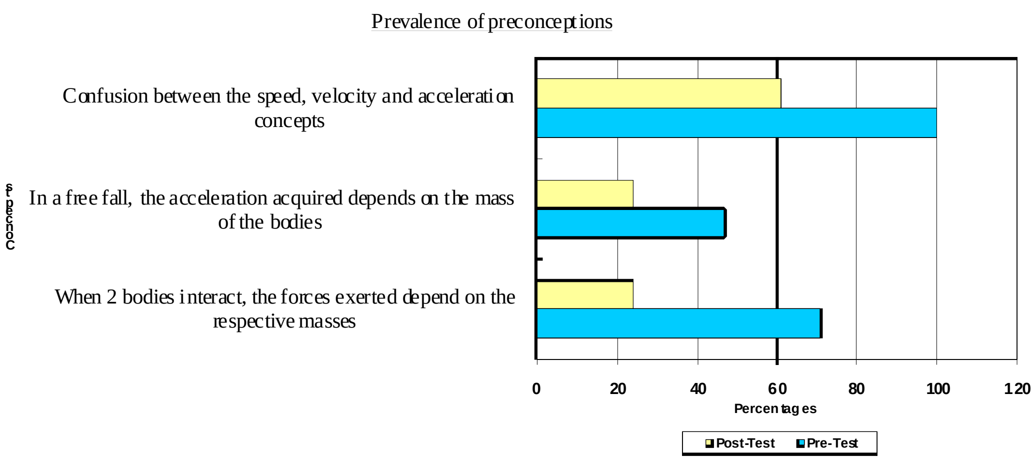

FIGURE 2. Persistent preconceptions in the "Moving Objects" unit after the MECIBA workshops.

2. Unit: "Nature of Light"

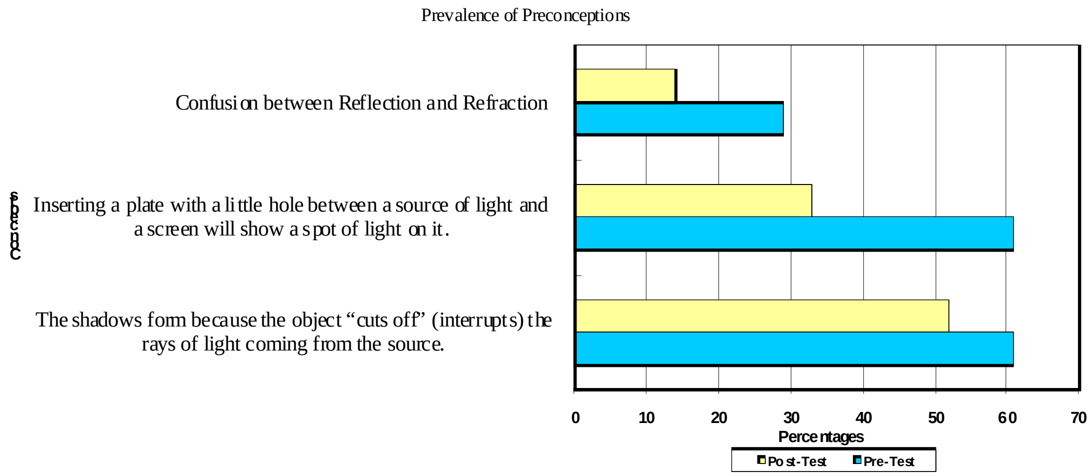

FIGURE 3. Persistent preconceptions in the "Nature of Light" unit after the MECIBA workshops.

V. CONCLUSIONS

The use of interviews as a tool to know the teachers' preconceptions gave us the possibility to manage a greater number of variables that could affect their answers, for example, the fact that the participating teachers are aware of their lack of knowledge and preparation.

The good results obtained on the post-test give us evidence that the methodology used for achieving a change in the teachers' cognitive structure is effective, although the fact that certain conceptual mistakes persisted after the workshops indicates that there may be non-considered factors in their development. For instance, the length of the workshops may not be long enough if we consider that every person learns with a different rhythm, and the participants' fear of facing up something new and somewhat unknown impeded their ability to state all their doubts and questions related to the subjects taught.

Besides, we believe that it is very important not to just create a conflict and dissatisfaction between ideas, but there must also exist a change in the individual's attitude about the ways he or she faces up to the new situations that rise. The person must really assimilate the new concepts to know how to apply them correctly in the future.

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REFERENCIAS

[1] OPPS guides, http://www.phys.lsu.edu/dept/opps/, Visited on August 2004.

[2] Gil, D. y De Guzmán, M., *Enseñanza de las Ciencias y la Matemática*, (Editorial Popular, España, 1993).

[3] Ausubel, D. P., Novak, J. D. y Hanesian, H., *Psicología Educativa. Un Punto de Vista Cognoscitivo. Spanish translation*, (Trillas, México, 1983).

[4] Brincones, I., *La construcción del conocimiento. Aplicaciones para la enseñanza de la Física*, (Ediciones de la Universidad Autónoma de Madrid, Madrid, 1995).

[5] Carretero, M., *Construir y enseñar. Las Ciencias Experimentales, (*Editorial Aique, Buenos Aires, 1996).

[6] Prosser, M., Trigwell, K. and Taylor, P., *A phenomenographic study of academics' conceptions of science learning and teaching*, Learning and Instruction **4**, 217-231 (1994).

[7] Strike, K. A. and Posner, G. J., A revisionist theory of conceptual change. In R. A. Duschl y R. J. Hamilton (Eds.), *Philosophy of Science, Cognitive Psychology and Educational Theory and Practice* (pp. 147-176), (State University of New York Press., Albany, New York, 1992).

[8] Kolb, D. A., *Experiential Learning: Experience as the Source of Learning and Development*, (Prentice-Hall Inc, Englewood Cliffs, NJ, 1984).

[9] Rodríguez, M., *Conocimiento previo y Cambio conceptual*, (Editorial Aique, Buenos Aires, 1999).

[10] Fetherstonhaugh, T. and Treagust, D. F., *Students' understanding of light and its properties: Teaching to engender conceptual change,* Science Education **76**, 653-672 (1992).

[11] Twigger, D., Byard, M., Driver, R., Draper, S., Hartley, R., Hennessy, S., Mohamed, R., O'Malley, C. E., O'Shea, T. and Scanlon, E., *The conception of force and motion of students aged between 10 and 15 years: an interview study designed to guide instruction*, International Journal of Sciences Education **16**, 215-229 (1994).

APPENDIX 1

Test Module 1: Moving Objects.

1. Light travels in a straight line with a constant speed of 300.000 km/s. What is its acceleration?
2. Two objects move on a straight line: a car, whose speed increases from 50 km/h to 60 km/h in certain time interval, and a bicycle, which starts at rest and reaches a speed of 10 km/h in the same time interval than the car. Which object has a greater acceleration?
3. If the speedometer of a car shows a constant speed of 40 km/h, is it correct to state that the velocity of the car is constant?
4. The speedometer of a car that travels north shows 60 km/h. The car moves beside another car that travels south at 60 km/h. Do the cars travel at the same speed? Do they travel with the same velocity?
5. A heavy book and a sheet of paper are released simultaneously from the same height.

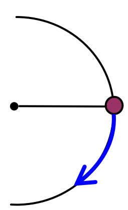
a) If they were to fall through air, which object would arrive first to the ground?
b) If they were to fall in vacuum, which object would arrive first to the ground?

6. Two bodies, one heavier than the other, fall freely near the surface of the Earth.

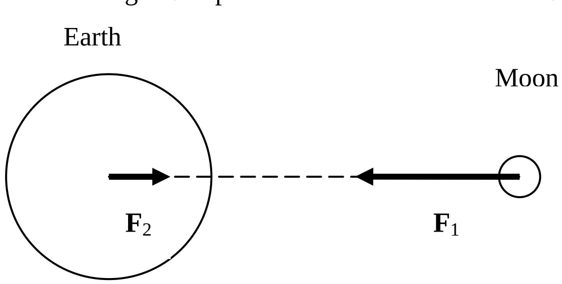
a) Which is the value of the free fall acceleration for the heavier object? and for the lighter object?
b) What is the name given to the acceleration of a body that falls freely?

7. A ball tied by a string to a fixed axis performs uniform circular motion.

a) Draw and specify all the forces that act on the ball.



8. A small car collides with a large, heavy loaded truck. During this interaction, is the force exerted by the car on the truck larger than, equal to, or less than the force exerted by the truck on the car?
9. It is well known that the Earth exerts an attractive force on the moon. Therefore, according to Newton's third Law, the moon also exerts a force on the Earth. The figure below was found in the internet. It shows these interaction forces between the Earth and the moon. However, there is a serious mistake in this figure. Explain in what consists this error.



10. Can a body in equilibrium be in motion? If possible, what kind of motion would it be?
11. Some people can quickly remove the tablecloth of a fully set table in such a way that the things on the table remain in their place. How would you explain this magician trick?
12. A man stands in a moving bus. If the bus conductor slows down abruptly, the man is "pushed" towards the front of the bus. How can you explain this fact?

APPENDIX 2

Interview Module 1: "Moving Objects"

Using your hand, you throw a ball vertically up with a given initial speed.

1. Describe the trajectory of the ball. Make a drawing.
2. Use arrows to show the velocity of the ball at several points of its trajectory.
3. Use arrows to show the acceleration of the ball at several points of its trajectory.
4. What forces act on the ball while it is in motion? Represent those forces using arrows.
5. What difference does it make if the motion takes place in air or in vacuum?
6. Let's assume that you stand inside a vacuum chamber on the surface of the Earth, and that you throw the ball up under the same conditions that before. Which trajectory will the ball follow in this case?
7. What will happen in this case with the velocity of the ball (in vacuum)?
8. What will happen in this case with the acceleration of the ball?
9. What forces act on the ball while it moves in vacuum?

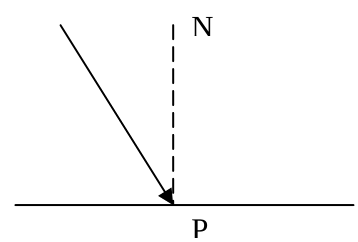
APPENDIX 3

Test Module 2: "Nature of Light"

1. We know that the Moon is not a source of light. Then, why is it possible for us to observe it?
2. Why is a shadow formed when we interpose an object in between a source of light and a wall?
3. The figure below shows a ray of light incident on a mirror (the line NP is perpendicular to the mirror's surface).

a) Draw, in an approximate way, the trajectory of the reflected ray.
b) Show in your drawing the angle of reflection.

If the angle of incidence is 32º, which is the value of the angle of reflection?



4. What evidence can you give for light propagation in vacuum?
5. Why well-polished metallic surfaces behave like mirrors?
6. Why does a black surface become hotter than a white surface when both of them are exposed to a light source for a long time?
7. Why do ambulances have the word "Ambulance" written backwards on their front? Explain your answer using a drawing.

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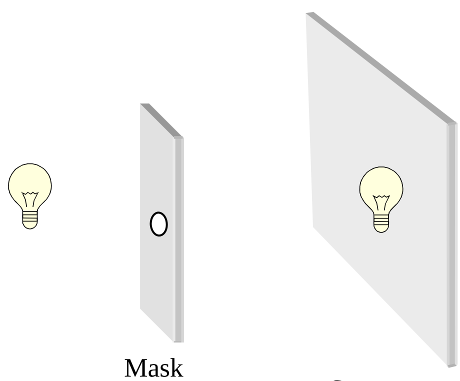
8. If you are in front of a plane mirror, at 1 m from it, at what distance is located your image from the mirror?
9. From the Earth we see the sky blue. However, astronauts far away of the Earth (for instance on the surface of the Moon) see the sky black. Explain this discrepancy.
10. You stand in a windowless, L-shaped room whose walls are non reflective. There is only one source of light in the room. Can you see the armchair located in the other extreme of the room, as shown in the figure?

11. A small bulb is in front of a screen in a dark room. If a mask with a small circular opening at its center is placed in between the bulb and the screen, and then the bulb is turned on, what will you see on the screen?



APPENDIX 4

Interview Module 2: "Nature of Light"

1. Why can we see an object placed in front of us, for instance, the pencil I hold in my hand?
2. Can we see the pencil if we are in a room that is completely dark? The room has no source of light at all.
3. While we are in the completely dark room of the previous question somebody hands you a flashlight turned on. Can we see the pencil? In what direction must the flashlight shine in order to see better the pencil?
4. If we put the flashlight in front of the pencil and behind of the pencil there is a wall, what do we see on the wall?

If in the last question the answer given is that a shadow appears on the wall, then the following question is asked:

5. What happens to the shadow if the pencil is moved away from the wall and closer to the flashlight?
6. Question on refraction: Why a spoon or a straw appears to be broken when introduced in a glass of water? See the attached figure.