

Science teachers' hypothetic-deductive skills: The pendulum problem



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Abstract

The purpose of this study was to examine the hypothetico-deductive skills demonstrated by teachers during the resolution of the pendulum problem. Specifically, we were interested in addressing the following: Do science-background teachers approach the solution of the pendulum problem in a scientific manner more frequently than non-science-background teachers? In order to answer this, we presented teachers with a pendulum with three different lengths and three different masses, in a manner similar to Inhelder and Piaget, and then asked them to answer a questionnaire. Participants were science education teachers that had either a science background or a non-science background. Results indicated that both science and non-science background teachers had difficulty in solving the problem correctly; that is, in identifying the single factor determining the frequency of the pendulum after experimenting with the provided lengths and masses. Results are discussed in the context of science teacher preparation and training. It is not our intent to “blame” teachers. Our expectation is to stimulate reflection upon the scientific skills teachers bring to their science classrooms. Content knowledge of the subject matter to be taught may not be enough. The scientific skills teachers use to solve science problems and that they may be “inadvertently” passing along to their students, appear to be equally important in the process of teaching-learning science.

Keywords: Hypothetico-deductive Thinking, Science Education.

Resumen

El propósito de este estudio fue examinar las habilidades hipotético-deductivas que los maestros demuestran durante la solución del problema del péndulo. Específicamente, teníamos interés en responder la siguiente pregunta: ¿Los maestros con formación en ciencias se aproximan a la solución del problema del péndulo de una manera científica más frecuentemente que los maestros que no tienen dicha formación en ciencias? Para contestar esto, presentamos a los maestros un péndulo con tres longitudes y tres masas diferentes, semejante a como Inhelder y Piaget hicieron en sus estudios, y después les pedimos que respondieran un cuestionario. Los participantes fueron maestros de ciencias, algunos de los cuales tenían formación en alguna área de las ciencias y otros no. Los resultados indican que tanto los maestros con formación en ciencias como aquellos que no la tienen, tuvieron dificultad en resolver el problema del péndulo correctamente, esto es, en identificar el único factor determinante de la frecuencia del péndulo después de haber experimentado con las diferentes longitudes y masas. Los resultados son discutidos en el contexto de la preparación y formación de maestros. No es nuestra intención “culpar” a los maestros. Lo que esperamos es provocar una reflexión sobre las habilidades científicas que los maestros llevan consigo a sus clases de ciencia. El conocimiento del contenido a ser enseñado parece no ser suficiente. Es decir, las habilidades científicas que los maestros usan en la resolución de problemas científicos, y que pueden estar pasando de una manera inadvertida a sus alumnos, parecen ser igualmente importantes en el proceso de enseñanza-aprendizaje de ciencias.

Palabras clave: Pensamiento hipotético-deductivo, Educación en Ciencias.

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I. INTRODUCTION

Hypothetic-deductive thinking was widely investigated by Piaget and colleagues in the Geneva School during the 1950's [1]. This type of thinking is the most characteristic of the Formal Operational stage of development according to Piaget's theory [2, 3]. A relevant aspect in relation to science education is that this hypothetic-deductive

reasoning is at the base of scientists' thinking [4, 5]; and therefore, very important to the learning and understanding of science. Investigations relating children's hypothetic-deductive skills with their ability to learn, especially in the context of science education, have been part of the education scenario [4, 6, 7, 8] since the time Inhelder and Piaget first presented their ideas about the onset and development of Formal Operations in their now classic

work *The growth of logical thinking: From childhood to adolescence* (GLT) [9]. In addition to Inhelder and Piaget, other researchers have investigated the hypothetic-deductive skills of children and adolescents [10, 6, 3], of different socioeconomic status and age [7] and from different cultures [11], pointing out their relevance for science education.

Our interest in hypothetic-deductive skills also arises from Piaget's [12] own analysis of the development of Formal Operational thinking in all people. That is, he put forth that this type of thinking would not be developed by all people in the same way, but that aptitude and environment would play an important role in the development of these skills, one of them being the hypothetic-deductive.

For science education, the unstated understanding has been that if educators know when children's thinking is "ready" to learn science, then they would be able to teach specific science content at that time. That is, teaching would occur at the time children had acquired the necessary skills to think as scientists, implying in this way that their science learning would be facilitated.

Even if this statement were right, partially right, or altogether wrong, an extremely important factor that we believe has received little attention by the science education research community is related to the teacher's hypothetic-deductive skills. Some authors have addressed similar questions suggesting that what teachers know about the nature of science may be as important as their ability to teach it. For example, Craven III, Hand and Prain [13] investigated the explicit and tacit conceptions of the nature of science among pre-service elementary school teachers. They asked their participants to answer the question "What is science?" to determine their level of explicit and implicit understanding of the nature of science. They asked this question several times throughout the 15 week period of a "science methods" course. What these authors found was that, initially, pre-service teachers' responses reflected a more explicit knowledge based on factual immediate information. As the weeks went by, and the activities of the course were completed, participants' answers began to show an implicit understanding of the nature of science, reflecting it as a multiple methods endeavor and as an enquiry activity. Other researchers have also examined the influence of teachers' epistemological beliefs on their teaching skills [14, 15] suggesting that these beliefs do in fact influence science teachers' thinking and calling for awareness of these beliefs when analyzing the practice of science teachers and their possible effect on students' learning.

We assume that the teaching-learning process is one that is constantly feeding-back on itself. Thus, we believe, that for science education to be successful, teachers' scientific skills, as well as their subject knowledge may be as important as knowing how students learn. In this particular work, we are interested in the hypothetic-deductive skills of teachers of science, even though we do not ignore that other pedagogical skills might be important as well [15]. Therefore, the purpose of this exploratory study is to

examine the hypothetic-deductive skills demonstrated by teachers during the resolution of the pendulum problem. Specifically, we are interested in addressing the following: Do science-background teachers approach the pendulum problem in a scientific manner more frequently than non-science-background teachers? We refer to hypothetic-deductive skills as the ability of making inferences and conclusions based on some type of evidence and in relation to hypotheses previously formulated [16]. We chose the pendulum problem as the activity in this project because "...pendulum investigations might still be used to assess higher order mental capacities and children's [*and adults*'] ability to reason proportionally, to control variables, to make inferences, to draw conclusions about the truth of hypotheses given certain evidence..." [11].

II. METHOD

In order to examine the hypothetic-deductive skills, we presented 20 participants with a pendulum with three different lengths and three different masses as Inhelder and Piaget [9] did in their studies. All 20 participants were involved in science education at some level. Two of them (10%) were students in a doctoral program of science education; 10 (50%) were students completing a Master's degree in science education; 5 (25%) were professors of education in charge of training future teachers that will be teaching science at the elementary school level; and 3 (15%) were professors teaching science courses (mathematics and biology) at the undergraduate level. Please note that not all doctoral and master level students possessed a bachelors' degree in science (i.e., physics, mathematics, chemistry or biology), but had diverse educational backgrounds (e.g., education, literature, arts). The average age of participants was 38 years old (range 31 to 52) and 15 (75%) of them were female. None of them had taught the topic of the pendulum.

We presented the pendulum with the three different lengths and masses, individually, to all participants and instructed them to manipulate these materials so that they could tell us which factor determined the frequency of the pendulum. There was no time limit and the participants were always accompanied by one of the authors during the activity, so that they could ask any questions they might have. After they indicated that they knew the answer, we asked them to complete a multiple-choice questionnaire with space to comment if they needed to add information we might have missed asking about.

III. RESULTS AND DISCUSSION

In order to determine if teachers' science-background influenced the solution of the pendulum problem, we looked at the results in two ways: 1) we divided the participants according to their stated formal training in science; that is, according to how much they self-identified as someone who had a history of taking science courses

during their training as a teacher (Table I). And, 2) we divided the participants according to their stated experience teaching science at any level from elementary school to college (Table II). Results indicate that both science and non-science background participants had difficulty in solving the problem correctly. That is, they had difficulty identifying the single factor determining the frequency of the pendulum (i.e., length alone) after experimenting with the different lengths and masses. However, more science-background teachers identified the correct factor versus participants who indicated a non-science background and those who said that had some-science background (Table I).

TABLE I. Participants' Formal Training in Science.

		What determines de frequency of the pendulum?*				
		Length N (%)	Length alone N (%)	Mass N (%)	Mass alone N (%)	Both together N (%)
Science Backgd	Yes (n=8)	7 (88)	5 (63)	2 (25)	0	3 (38)
	Não (n=6)	5 (83)	1 (17)	4 (67)	0	4 (67)
	Some (n=6)	6 (100)	2 (33)	4 (67)	0	4 (67)

*Participants could mark more than one response. Therefore, percentages are not summative.

Similarly, more teachers with experience teaching science identified the correct factor versus participants who reported that had never taught science (Table II). None of the participants reported that mass alone was the single factor determining the frequency of the pendulum; however, more than half of the participants thought that both the length and mass together determined the frequency of the pendulum (Tables I and II).

TABLE II. Participants' Science Teaching Experience.

		What determines de frequency of the pendulum?*				
		Length N (%)	Length alone N (%)	Mass N (%)	Mass alone N (%)	Both together N (%)
STE**	Teaches or Taught Sci. (n=12)	11 (92)	6 (50)	5 (42)	0	6 (50)
	Never Taught Sci. (n=8)	7 (88)	2 (25)	5 (63)	0	5 (63)

*Participants could mark more than one response. Therefore, percentages are not summative.

**STE=Science Teaching Experience.

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What these results suggest is that having a science background and science teaching experience allow approaching the resolution of a problem in a more hypothetico-deductive way. It was observed that most of the teachers that arrived at the correct solution had a systematic approach of manipulating the variables (i.e., length and mass), took notes to keep track of their combination of variables, made predictions, and re-tested their predictions before indicating they knew the answer. That is, they used a hypothetico-deductive approach to solve the pendulum problem. Contrary to this, teachers that had limited or no science background, took an approach of trial and error, were non-systematic, did not take notes, did not make predictions, and made conclusions based on incomplete manipulation of variables.

These results, although not yet statistically significant due to the small number of participants, are encouraging to design more methodologically rigorous studies to look at the relevance of specific science training (i.e., physics, chemistry, biology or mathematics) in teaching science. Additionally, we believe that teachers need to be aware of the way they are approaching problem resolution during science lessons. It has been reported, in the science education literature, that students are not learning science, in part, because their teachers' inadequate preparation [11, 17]. All of our participants are involved in science education at some level. Even the ones that reported not having experience teaching science or those who did not have a science background will be expected to teach science after graduation. So, why not teach science with a scientific approach in mind? That is, why not prepare teachers to train their students to approach problem resolution in a scientific manner? In this respect, we agree with Lawson [8], who indicates that science education research, even though improving in their way of conducting and reporting research, still needs to address important questions and be more consistent with regard to the "scientificity" of science education research. Extending this thought, we also wonder about the implications of this science education research for science teaching practice.

It is not our intent to "blame" teachers for the difficulties of science education. We instead look to stimulate reflection that could potentially lead to action for improving the scientific skills teachers bring to their science classrooms and how these skills can best be taught to their students. According to our results, knowledge of the scientific subject matter to be taught may not be enough. The scientific skills, in this case the hypothetico-deductive ones that teachers demonstrate, or not, during the resolution of science problems may be equally important for students' science learning.

IV. CONCLUSIONS

Science education teachers enter the teaching field with varied levels of skills both in terms of subject knowledge and in terms of pedagogical skills. Even though it is desirable for them to have a background in a science area

such as physics or chemistry, it is not always the case, which potentially creates an uneven science education practice. Some skills, however, like the hypothetic-deductive ones, may be considered content independent. In this way, the development of these skills and their application by science teachers should be at the core of their training. At some level, these words may sound out of context; however, we noticed that both science-background and non-science-background teachers had difficulty solving the pendulum problem correctly, which greatly depends on a scientific approach to identify the observable effects of a single variable on the frequency of the pendulum (i.e., the length of the pendulum). Much has been said about the deficits in science education around the world [17, 18], and how these deficits may be related to teacher preparation; that is, to their content knowledge and pedagogical skills [19, 15]. We do agree that content knowledge and pedagogical skills are indeed an area that needs to be addressed; however, considering teachers' skills to think as scientists may be equally important in science education.

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REFERENCES

- [1] Bond, T. G., *Piaget and the pendulum*, Science & Education **13**, 389-399 (2004).
- [2] Ginsburg, H. and Opper, S., *Piaget y la teoría del desarrollo intelectual*, (Prentice Hall Hispanoamericana, México, 1977), p. 228.
- [3] Kuhn, D., *Formal operations from a twenty-first century perspective*, Human Development **51**, 48-55 (2008).
- [4] Fuller, R. G., Karplus, R. and Lawson, A. E., *Can physics develop reasoning?*, Physics Today **30**, 23-28 (1977).
- [5] Sumida, M., *The reproduction of scientific understanding about pendulum motion in the public*, Science & Education **13**, 473-492 (2004).

- [6] Kuhn, D. and Angelev, J., *An experimental study of the development of formal operational thought*, Child Development **47**, 697-706 (1976).
- [7] Mwamwenda, T. S., *Formal operations and academic achievement*, The Journal of Psychology **127**, 99-103 (1992).
- [8] Lawson, A. E., *How "scientific" is science education research?*, Journal of Research in Science Teaching **47**, 257-275 (2010).
- [9] Inhelder, B. and Piaget, J., *The growth of logical thinking: from childhood to adolescence*, (Basic Books, Inc., USA, 1958), p. 356.
- [10] Zachos, P., *Pendulum phenomena and the assessment of scientific inquiry capabilities*, Science & Education **13**, 743-756 (2004).
- [11] Matthews, M. R., Gauld, C. and Stinner, A., *The pendulum: Its place in science, culture and pedagogy*, Science & Education **13**, 261-277 (2004).
- [12] Piaget, J., *Intellectual evolution from adolescence to adulthood*, Human Development **51**, 40-47 (2008). Reprint of Human Development (1972), pp. 1-12.
- [13] Craven III, J. A., Hand, B. and Prain, V., *Assessing explicit and tacit conceptions of the nature of science among preservice elementary teachers*, International Journal of Science Education **24**, 785-802 (2002).
- [14] Tsai, C. C., *Nested epistemologies: science teachers' beliefs of teaching, learning and science*, International Journal of Science Education **24**, 771-783 (2002).
- [15] Barnett, J. and Hodson, D., *Pedagogical context knowledge: Toward a fuller understanding of what good science teachers know*, Science Teacher Education **85**, 426-453 (2001).
- [16] Stafford, E., *What the pendulum can tell educators about children's scientific reasoning*, Science & Education **13**, 757-790 (2004).
- [17] Fensham, P. J., *Science education policy-making: Eleven emerging issues*, (UNESCO, Paris, 2008), p. 47.
- [18] Programme for International Student Assessment (PISA). <http://www.pisa.oecd.org/dataoecd/54/12/46643496.pdf>, accessed February 27, 2010, 12:20 pm.
- [19] Thurmond, C. K. and Lee, O., *Perceptions of scientific literacy and elementary teacher preparation held by science professors and science education professors*, Florida Journal of Educational Research **40**, 5-27 (2000).