New Perspectives in Science Education
International Conference
NEW PERSPECTIVES in SCIENCE EDUCATION


Assessment of the Transfer of Inductive Reasoning Skills in the Context of Science Teaching

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Abstract

The need to develop critical thinking skills in students is currently recognized at all educational levels. This is especially relevant in the case of science education, since there is a clear relationship between the components of critical thinking and the processes involved in scientific practice. From the cognitive psychological approach, the components of critical thinking that can be improved through education include the different forms of reasoning, decision making, and problem solving. At the university level, it is normally assumed that reasoning skills have been developed at the school level and the choice is made to promote the development of skills for problem solving, decision making, and argumentation. However, it is necessary to investigate whether the process at the secondary education stage achieves the expected goals, especially if an effective transfer of the skills learned in a context of explicit teaching of them is achieved, towards contextualized situations in science teaching. The objective of this work was to evaluate the level of transfer of inductive reasoning skills with fourth-level high school students from a Peruvian school. The students participated in a teaching module of different forms of inductive reasoning, including: inductive generalization, causal reasoning, analogical reasoning and hypothetical reasoning. Subsequently, the application of these skills was evaluated in the context of teaching a scientific topic. The results showed better achievements in the case of inductive generalization and in the other three cases an effective transfer was not achieved. This work is a good reference to improve the teaching strategies of reasoning skills and the transfer of these in situations of other disciplines, particularly in the teaching of sciences.

Keywords: *Critical thinking, reasoning skills, secondary education.*

1. Introduction

In the educational context, the last decades have been characterized by a permanent search to redefine the essential aspects that constitute the purpose of educational processes at all levels. In a dynamic context of permanent change in terms of resources, social needs, technological development, global problems, among others, different profiles of essential competencies are permanently proposed for the training of people through education, highlighting more and more the relevance of critical thinking, together with the resolution of complex problems, creativity, leadership and teamwork [1], [2].

For many disciplines, and in particular for science education, the development of scientific thinking and critical thinking in students is considered indispensable for the formation of responsible citizens in the face of current society demands. Both are intellectual processes that maintain a very close relationship, although they can differ in terms of some of the cognitive skills involved and the purposes of each of them [3].

Cognitive psychology has identified a set of skills that contribute, together with attitudes and metacognition, to the development of critical thinking. Saiz [4] considers three types of reasoning: deductive, inductive and practical, in addition to decision-making and problem-solving skills. These last two skills allow the application of a combination of basic reasoning skills and are the ones most frequently promoted in proposals for strategies to develop critical thinking in higher education. It is normally assumed that basic reasoning skills have been developed at the secondary level, however, there is not enough evidence about the strategies used for their teaching and neither about the achievement in the transfer of these skills in different contexts. One of the main objectives of the proposals for teaching critical thinking is precisely that an effective transfer of these skills can be achieved in different situations, both academic and non-academic [5].

The objective of this work was to evaluate the level of transfer of inductive reasoning skills with fourth-grade high school students from a Peruvian school. To this end, a pilot program was designed and implemented that consisted of two modules. In the first of them, direct teaching of the four types of

inductive reasoning was carried out: inductive generalization, causal reasoning, analogical reasoning and hypothetical reasoning. The second module was carried out four months later in the context of teaching the topic “Evolution of species”. In this case, the application of the four types of inductive reasoning was evaluated through situations contextualized in the aforementioned topic.

2. Methodology

2.1 Participants

The participants in this study were 19 fourth-year high school students from an Emblematic Peruvian Educational Institution. They were aged between 15 - 16 years. The educational institution has a 100% female population.

2.2 Context of the study

The educational institution where this study was conducted was founded in 1947 and currently has 1,250 students distributed across the initial, primary and secondary levels. This institution was included in 2010 as a member of the so-called emblematic institutions, which received special financial support from the government to remodel and modernize their infrastructure.
The students participating in the study were part of a pilot plan in which a first module was programmed to explicitly teach the characteristics of inductive reasoning, considering its four types: inductive generalization, causal reasoning, analogical reasoning and hypothetical reasoning. For each of them, illustrative examples and application activities were proposed so that the students could check their level of understanding of the topic. Finally, the students answered an evaluation test on the topic. This module was developed in two sessions of 90 minutes each.
Four months after the first module was completed, the topic “Evolution of Species” was worked on in the area of Science and Technology. This topic is linked to the work of the competence “Explain the physical world based on knowledge about living beings, matter and energy, biodiversity, Earth and the Universe” of the secondary education curriculum established by the Peruvian Ministry of Education [6]. For this competence, the ability “Understand and use knowledge about living beings, matter and energy, biodiversity, Earth and the Universe” is considered. In this ability, students must “Establish relationships between various concepts and transfer them to new situations. This allows them to build representations of the natural and artificial world, which are evident when the student explains, exemplifies, applies, justifies, compares, contextualizes and generalizes their knowledge”.
The topic was worked on during three sessions of 90 minutes each, implementing active methodologies. At the end of the module, a structured test was applied with the different types of inductive reasoning contextualized in the topic of “Evolution of Species”.

2.3 Assessment

Two tests were developed to assess the application of inductive reasoning. The first test was developed in the context of the first module in which the four types of inductive reasoning were explicitly taught: inductive generalization, causal reasoning, analogical reasoning and hypothetical reasoning. For each of them, the student had to analyze situations in which it was necessary to apply one of them. The second test was developed with the same characteristics, but the situations posed were contextualized in the topic “Evolution of species”.
In both cases the score followed the following protocol:
0.25: Correctly concludes
0.50: Makes a proposal with a partial analysis of the information
0.75: Correctly applies the logical principle
1.00: Proposes a hypothesis by correctly analyzing the information

2.4 Analysis of data

The data were analyzed using Statistical Package for the Social Sciences (SPSS) 29 software ®. Level alpha was established a priori in 0,05.
The frequency of cases in each indicator of each of the types of inductive reasoning evaluated for both tests was determined. These frequencies were expressed as a percentage relative to the total number of participating students.

The scores achieved in each of the types of reasoning for both tests were determined and compared using the Wilcoxon Signed Rank test for related samples.

3. Results

Figure 1 shows the frequency of cases, expressed as a percentage, for each indicator applied to assess achievements in the inductive generalization category, in both modules.

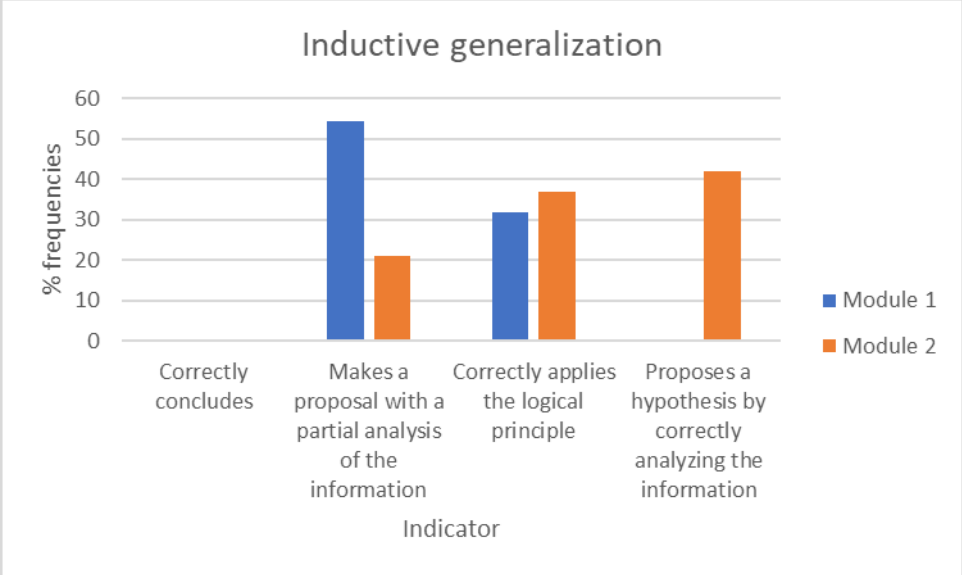

Fig. 1. Inductive generalization: % frequencies in each indicator for the two modules

It can be observed that the results are clearly better in the second module, which is evidence that the students managed to apply this type of reasoning in contexts different from the one used in the training, so it is evident that there was a good transfer in this case.
Figure 2 shows the frequency of cases, expressed as a percentage, for each indicator applied to assess achievements in the causal reasoning category, in both modules.

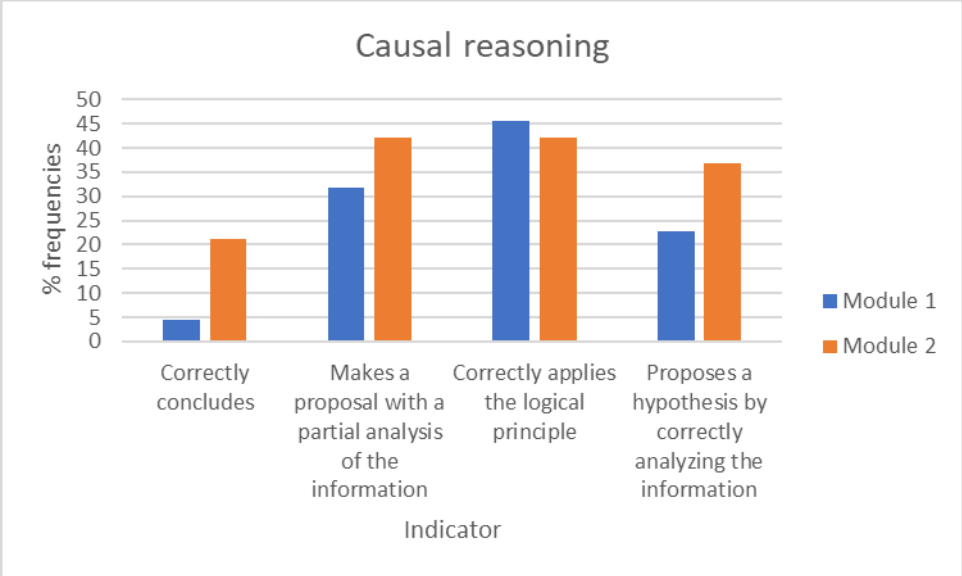

Fig. 2. Causal reasoning: % frequencies in each indicator for the two modules

In this case, it can be observed that, although the indicator with the highest score had a higher frequency of cases in the second module, the frequency of cases in the indicator with the lowest score also increased. It cannot be said that there was a good transfer to the application of causal reasoning.
Figure 3 shows the frequency of cases, expressed as a percentage, for each indicator applied to assess achievements in the analogical reasoning category, in both modules.

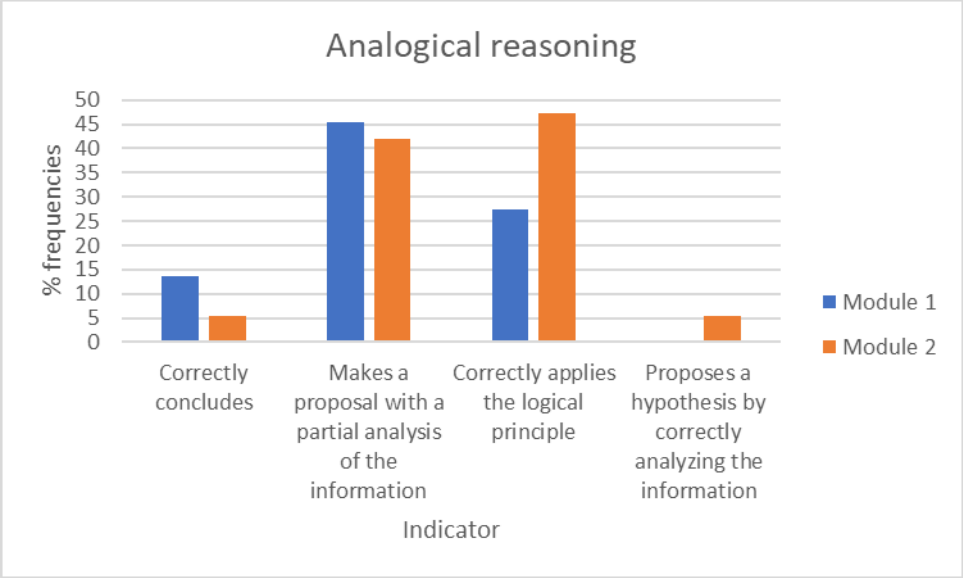

Fig. 3. Analogical reasoning: % frequencies in each indicator for the two modules

The evaluation of the application of analogical reasoning showed a minimal improvement in the case of module 2, with a small percentage of cases in the highest-scoring indicator. However, the differences do not allow us to demonstrate that there has been a good transfer in this case.
Figure 4 shows the frequency of cases, expressed as a percentage, for each indicator applied to assess achievements in the hypothetical reasoning category, in both modules.

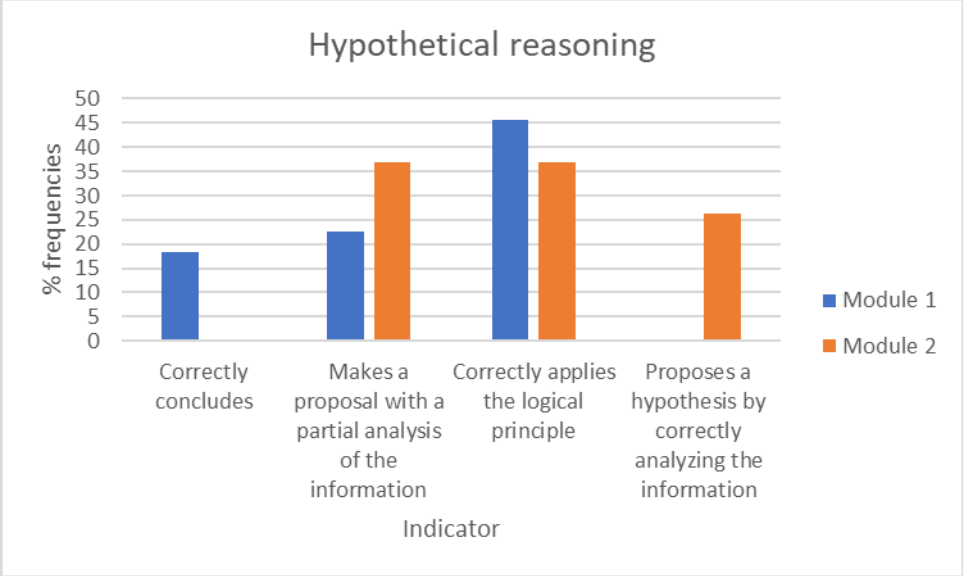

Fig. 4. Hypothetical reasoning: % frequencies in each indicator for the two modules

Although a better result can be observed for the application of hypothetical reasoning in module 2, the frequency of cases in the intermediate score indicators is very similar in both modules, so it cannot be stated that a good transfer has occurred.
Table 1 shows the descriptive statistics for the four types of inductive reasoning assessed in both modules.

Table 1. Descriptive statistics for the four types of inductive reasoning assessed in the two modules

Type of inductive reasoning	M		SD	
	Module 1 (N = 19)	Module 2 (N = 19)	Module 1 (N = 19)	Module 2 (N = 19)
Inductive generalization	0,5921	0,8026	0,1239	0,1968
Causal reasoning	0,6316	0,6974	0,1529	0,1968
Analogical reasoning	0,5395	0,6316	0,1721	0,1742
Hypothetical reasoning	0,5789	0,7237	0,2050	0,2023

The application of the Wilcoxon Signed Rank test for related samples, with a significance level of 0.05, showed significant differences between the results obtained for the two modules only in the case of inductive generalization (Z: -2.961; Asymp. Sig. (2-tailed): 0.003). This result is consistent with what was analyzed from the comparison of the frequency of cases by indicator.

In this sense, it can be stated that a good transfer was found in the application of this type of reasoning, but not in the other three. However, there were acceptable results in these other types of reasoning, so the pilot carried out has shown the aspects that need to be strengthened in the review of the strategy to promote these skills in students.

4. Conclusions

The results obtained in the pilot program described have been generally good, as consistency was observed in the application of the different types of inductive reasoning. While a significant achievement was only observed in the case of inductive generalization, which is more easily learned by students, in the other three types of reasoning there were improvements and not setbacks in the application of these in the context used in the second module. These three types of reasoning are more closely related to the skills involved in the use of scientific thinking.

The reported findings are relevant to the review of strategies that seek to promote basic critical thinking skills and can also serve as a starting point for the development of activities that can be used by secondary school teachers to improve their work with students.

Communication between secondary and higher education is essential to reinforce the foundations of student training and seeking points of articulation such as the one sought in this study can be very relevant elements in this purpose.

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