

Case Report

A Zone of Proximal Development Process in the Selective Disposal of Urban Solid Waste: Problem Solving with Two Assembled Materials

Conrado Ruiz-Hernández, Alma D. Lupercio-Lozano, Thalía A. Bernal-González

Unit of Interdisciplinary of Health and Education Sciences - FES Iztacala, National Autonomous University of Mexico (UNAM), Tlalnepantla, México

Email address:

educa.ambiente.cyma18@gmail.com (C. Ruiz-Hernández), lupercioalma09@gmail.com (A. D. Lupercio-Lozano),

thalia.ame.bernal@gmail.com (T. A. Bernal-González)

*Corresponding author

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Abstract: The zone of proximal development (ZPD) is a constructivist concept associated with learning processes involving the participation of a mediator or facilitator. In a previous study, our group developed an observation model that can be used to study learning processes of this type by measuring the fine skills involved in the selective disposal of Urban Solid Waste, a topic of environmental education involving numerous difficulties. We also developed an approach to evaluate the occurrence of a ZPD event using a mathematical problem-solving example. Combining both proposals, we carried out a quasi-experimental exercise in 2017, in which we tried to observe a zone of proximal development process in the resolution of two problems involving the selective disposal of Urban Solid Waste, one of them of very high difficulty and the other of moderate difficulty. The present work aims to show why selective disposal is a difficult and complicated environmental task. We worked with two groups of university students, a "control" group and a "quasi-experimental" group, with forty members each. We were able to verify the occurrence of a ZPD process in some participants of the "quasi-experimental" group.

Keywords: Education for Recycling, Environmental Education, Occasional Assembled-Waste Disposal, Structural Assembled-Waste Disposal, Environmental Task, Cognitive Particularity

1. Introduction

The genesis of learning related to problem-solving, especially when the process is carried out in cooperation with partners (under the presumption that at least one of the participants is experienced), constitutes a pedagogical dynamic of strategic value [1]. There are several concepts associated with constructivism (a theory that seeks to provide a materialistic explanation of learning by taking into account the social environment of each individual) that are based on the practice of problem-solving [2, 3, 4]. Two of those concepts are used in the present work: cognitive transfer or T (the application of knowledge or skills used by one subject to

solve a problem on his own, to the solution of a related problem of greater complexity), and zone of proximal development or ZPD (when the subject's ability is not sufficient to solve a problem independently and he requires guidance or assistance provided, directly or indirectly, by a facilitator or expert) [1, 5]. In socio-educational and psycho-pedagogical research, the latter concept is used for various purposes, mainly in special education; it is rarely used in environmental education, which we recognize as a weakness of the field

In a recent study carried out by our group, we used the term *cognitive particularity* with the intention of making more precise experimental or quasi-experimental observations. This concept is not part of the pedagogical vocabulary; for the

purposes of this article, "it consists of a learning situation of minimal dimension, with high thematic specificity associated with the solution of a problem, which the subject experiences without the occurrence of cognitive transfer, in a clear process of ZPD, which requires the help of a facilitator or "expert" [1]. We recognize that educational interventions in this type of situations can only be of short duration, and thus the expected impact is limited [6, 7, 8]. Moreover, these interventions cannot solve the problem of the integrated management of urban solid waste (USW), given its magnitude and complexity [9, 10]. Nevertheless, the observations carried out in the present work made it possible to obtain consistent short-term results, even from individual or group sessions of one hour or less [11].

The selective disposal of USW, especially when different types of waste materials are mixed together, can be a very difficult task, which makes it an appropriate field for the study of cognitive problems related to the occurrence of ZPD events and other educational topics [12]. The problems described below are proposed as *cognitive particularities* that can serve as indicators of how to effectively assess the fine skills involved in the selective disposal of USW.

2. Description of the Problems

The study of these two problems of USW disposal allowed us to deepen our experimental or quasi-experimental analysis of the fine skills involved in the selective disposal of regular garbage materials in tests carried out in school communities of different educational levels [13]. The first problem (P) is considerably less difficult than the second one (P'), which in previous studies has shown to be even more difficult than some arithmetic problems [12]. A clear difference between the difficulty of P (low or medium difficulty) and P' (high difficulty) is crucial for the correct identification, with statistical validation, of a process that is similar or very similar to a ZPD in a comparative study between groups.

Problems:

P: selective disposal of an aluminum can, separating it from a plastic straw partially located inside the can. Success is only achieved if the aluminum is deposited without the straw in a container that is exclusively for "metal". The solution of this problem is of medium difficulty, since the presence of the plastic straw inside the aluminum can is only occasional.

P': selective disposal of a glass bottle with a plastic cap. Success is only achieved if the glass bottle is deposited without the cap in a container that is exclusively for "glass". The solution of this problem is of very high difficulty because the plastic lid is an integral part of the bottle, although it is made of a material that is different from glass, which is not easily identifiable, and can be separated from the bottle.

These waste materials, clean and integrated into the indicated assemblages (aluminum can with plastic straw and glass bottle with plastic cap), were handed to the respondents one after the other: first problem P and then problem P'. In the control group, no intervention was made to provide help or guidance in the solution of P and P'. In the quasi-experimental

group, there was a brief intervention to provide help or guidance but only in the immediate moment before the presentation of problem P' (this is explained further below). In both groups, the materials corresponding to problems P and P' were delivered to the respondents inside two opaque lidded plastic boxes, which the participants had to open to find the assembled materials and then find the solution to each of the problems [14, 15].

The trash containers provided to the respondents, this being a multiple-choice test, were labelled as follows: plastic, metal, glass, writing paper/cardboard and everything else (five alternative responses). More options could be included in further tests.

3. Mathematical Approach

We have been developing for several years an experimental or quasi-experimental approach for the study of the zone of proximal development (ZPD). This approach is based on the use of the following equation [8]:

$$ZPD = P' - T$$

Where ZPD is determined, or, more properly, inferred, by the number of correct solutions that the respondents find for P' minus the value of T (cognitive transfer), which we assume is reflected in the coincidence of correct solutions between the control and the quasi-experimental groups for problems P and P'. The results thus obtained can be treated statistically using Student's t-test or analysis of variance.

4. Quasi-experimental Design

4.1. Objective

To carry out a quasi-experimental demonstration of the occurrence of ZPD events in an exercise of selective disposal of urban solid waste, with the participation of university students.

4.2. Hypothesis

For the purposes of this study, the occurrence of a zone of proximal development process is verified when the capacity of the subjects to autonomously solve a given problem exceeds what can be attributed exclusively to cognitive transfer.

4.3. Subjects and Procedure

Two groups of university science students, with forty students each, participated in a quasi-experimental exercise that aimed to evaluate the performance of each individual student in a didactic situation related to the selective disposal of waste materials. One of the groups was used as control. The exercise was carried out in a small room, which contained information posters on the culture of recycling and the need to appropriately separate waste materials, and, on a table, a set of trash containers (small plastic trays with the corresponding label) labelled as follows: plastic, metal, glass, writing

paper/cardboard and everything else. The quasi-experimental treatment, applied only at the time immediately preceding the presentation of P', was to make the students read the following text (written on a printed card): "The optimal use of garbage requires a careful separation of waste residues by the type of material. Look closely and dispose of what is inside the box as requested". The respondents then opened the plastic box containing P' and proceeded to perform the requested action. Problem P had been solved before without any guidance,

except for the labels on the trash containers. The control group solved P and P' are without any intervention (without reading the card); the participants were asked only to solve problem P (green box) first and only then solve problem P' (red box).

5. Results

The following figure shows the results observed in both treatments:

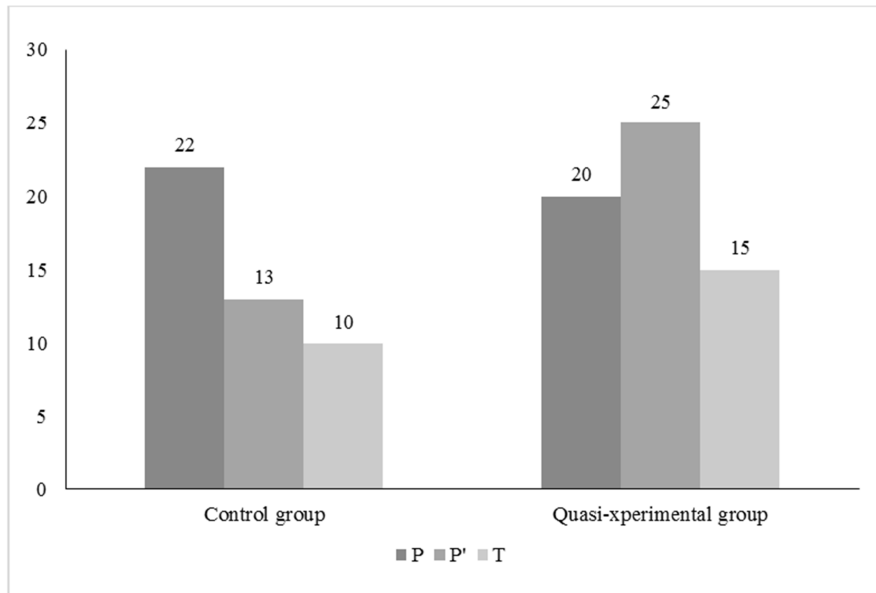


Figure 1. Success in solving the problems and coincidence of solutions between both groups.

The observed results, after applying the equation $ZPD = P' - T$, shows a value of 3 for the control group and a value of 10 for the quasi-experimental group. We infer that the value of this difference ($P' - T$) in the control group (where there was no intervention or orientation) represents a possible cognitive transfer. In the case of the "quasi-experimental" group, for which there was an intervention or orientation in the solving of P', we assumed that the value of the difference indicated that the process was similar to a zone of proximal development. The difference between the two groups of students was $10 - 3 = 7$, which reached a statistical confidence level of 97.5% in a two-tailed Student's t-test ($40 + 40 - 2 = 78$ degrees of freedom).

6. Analysis of Interesting Cases

In the control group, two participants who correctly separated the aluminum can from the plastic straw and also initially separated the glass bottle from the plastic cap, were confused at the end and put back the cap on the bottle before depositing it in the container labeled "glass". This confusion is very common in the case of waste materials that are mixed together in "structural assemblages" (in which two or more components made of different materials form part of the same container). In the same group (control), three participants who had previously made a mistake in P, succeeded in finding the correct solution for P'. In these three cases, we cannot attribute

the success in P' to a ZPD process or to cognitive transfer, but rather to a zone of real development (a phase that is part of the ZPD, but determined by the subject's own capacity) that may be explained by the training they had for solving P (which they solved incorrectly) or by the possibility that they paid greater attention to the solving of P', lack of attention being the main reason that causes mistakes in this type of problems.

In the quasi-experimental group, this type of situation was not observed, most likely due to the intervention we carried out before the presentation of P', which clearly had an important effect, particularly in making the participants pay more attention to correctly separate the waste materials found in the boxes. The effect of the intervention was particularly evident in the case of P', which suggests the convenience of developing specific strategies to encourage the occurrence of the ZPD in the selective disposal of USW and other type of environmentally-friendly tasks.

7. Discussion

The quasi-experimental design that we applied in this exercise lead us to think that replicating this observation model with groups of university students, under conditions in which the whole evaluation of the tasks can be carried out at the same time and place, could allow to make fully experimental observations [16]. Regarding the identification of the occurrence of a ZPD process, especially in the

quasi-experimental group, this study cannot be exempt of false positives and negatives (which are practically unavoidable in the field of social and educational research). Furthermore, the occurrence of correct solutions in P' together with wrong solutions in P, which was observed in some participants of the control group, indicate the participation of other phases of the ZPD (such as zones of real and potential development) that do not involve the participation of an external facilitator or guide. In such cases, the solution given to the problems has its origin in the subject's own internal capacity, which certainly constitutes a still largely unexplored and very complex research topic [17, 18, 19, 20].

8. Conclusion

We fulfilled the objective of making a quasi-experimental observation of a process similar or very similar to the ZPD in an exercise of differential disposal of USW with waste materials presented in assemblages. We also confirmed the usefulness of this procedure for measuring fine skills associated with the correct disposal of waste materials found in common garbage. This constitutes a contribution to the fields of environmental education, recycling culture and environmental psycho-pedagogy.

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