Towards a philosophy-inspired learning environment about biological classification: Insights from the 1st cycle of a design research

EFTYCHIA VALANIDOU, MARIDA ERGAZAKI, RENIA GASPARATOU

Department of Educational Sciences
and Early Childhood Education
University of Patras
Greece
evalanidou@upatras.gr
ergazaki@upatras.gr
gasparat@upatras.gr

ABSTRACT

This paper reports on the case study of the 1st cycle of a design research, which aims at designing a biological learning environment (LE) based on philosophical theories of concept formation. The aim of the LE is to support primary school students in constructing biological concepts such as 'fish', 'amphibian', 'reptile', 'bird', and 'mammal', and enhancing their categorization skills. The design principles of the 1st version of the LE, as well as the results of its implementation with 19 fifth graders and particularly their pre/post-ideas about the classes of vertebrate animals are thoroughly discussed in the paper.

KEYWORDS

Concept formation, philosophical theories, biology education, vertebrate classes

RÉSUMÉ

Cet article présente la première étape d'un projet de recherche, qui vise à concevoir un environnement d'apprentissage (EA) biologique basé sur les théories philosophiques de la formation de concepts. L'EA a pour objectif d'aider les élèves du primaire à élaborer des concepts biologiques tels que 'poisson', 'amphibien', 'reptile', 'oiseau' et 'mammifère', et à améliorer leurs compétences en matière de catégorisation. Les principes de conception de la 1ère version de l'EA, ainsi que les résultats de sa mise en œuvre avec 19 élèves de 10-11 ans *et en particulier leurs idées antérieures/postérieures sur les classes de vertébrés sont discutés en détail.*

MOTS-CLÉS

Formation des concepts, théories philosophiques, biologie, classes de vertébrés

THEORETICAL FRAMEWORK

Categorization is a basic thinking skill. We use mental categories, that is concepts like table, mammal or toy, in order to memorize information, make inferences, generalize, etc. Depending on the task we are performing, we categorize in many different ways, all of which are useful for our lives (Markman, 1989). Biology education, however, largely depends on tuning children's categorization in ways that would help them understand biological categories like animal, plant, fish, etc. (Ergazaki, Gasparatou & Valanidou, 2018). Young children often misidentify and misunderstand such biological concepts. For example, they often think that bats are birds, dolphins are fish (Natadze, 1963), sea turtles and crocodiles are amphibians (Yen, Yao & Chiu, 2004); in fact, they hardly discriminate among reptiles and amphibians (Yen et al., 2004). What's more, such naive ideas seem to be rather resistant, even after biology lessons (Kattmann, 2001). So, we need to find ways to help children understand biological categories (Allen, 2015; Barman, Stein, McNair & Barman, 2006; Trowbridge & Mintzes, 1988).

In everyday life, categorizing and re-categorizing the world around us is a rather easy endeavor. I can categorize books by author and then re-categorize them by subject, if asked to do so; I can consider Max as a pet and a dog and a beloved friend. When children get to school, they have already mastered such skills and are already rather flexible when categorizing; in fact, they easily reconsider their own categories when provided with new information (Murphy, 2002). When in a science class however, it seems that children find it hard to renegotiate certain categories. Perhaps then, there is something in this particular context that works against their categorization flexibility. Indeed, science education often requires that children quickly link concepts they might already employ with lots of newly acquired information. It is as if we expect children to easily mimic the ways scientific dictionaries work: connect terms with information about whatever the term refers to. So, while science education depends on children revising certain categories, it sometimes seems to work against this skill and invite children into a rather rigid and counterintuitive process of categorizing.

With this in mind, we decided to investigate whether we could help children develop alternative categorization strategies for concept formation, like the ones suggested by philosophers (Gasparatou & Ergazaki, 2016). More specifically, (a) *classical theory* suggests that we categorize, e.g., individual birds under the concept bird, by articulating definitions that describe the necessary and sufficient conditions of being a bird (Earl, 2006). On the other hand, (b) *family resemblance inspired theories* imply that we categorize, e.g., individual birds under the concept bird, by intuitively grasping several bird-shared features, that may not be common to all birds. So, I categorize a chicken as a bird because it has feathers, whereas I categorize an eagle as a bird for a different reason: because it flies (Kenny, 2010; Wittgenstein, 1958). Philosophers and psychologists still debate on which of such strategies is typical for humans or which we employ for which task (Murphy, 2002). It might well be the case however, that we mix and match strategies depending on the task or the context (Markman, 1989). So, it is worth exploring whether mixing and matching strategies implied by the above philosophical theories can help us design learning environments that facilitate children's categorization of living organisms.

Thus, our study addresses the question of whether it is feasible to design a philosophy-based learning environment that could effectively support primary school students in (a) constructing biological concepts such as e.g. fish or bird, and (b) enhancing their categorization skills. In this paper, we are particularly concerned with (a); that is, evaluating the first version of our learning environment by identifying students' ideas before and after taking part in it. So, the question here is: *'How do primary school students reason about the biological concepts of* *mammal, bird, reptile, amphibian, and fish before and after their participation in the learning environment?'*. More specifically, 'do they group vertebrate animals in *class*-groups?', 'how do they justify their groupings?', and 'how they use the quantifiers 'all' or 'some' when reasoning about specific features of vertebrates classes?'.

METHODOLOGICAL FRAMEWORK

The overview of the study

This paper reports on a case study we performed in the first cycle of a design research (Akker, Gravenmeijer, McKenney & Nieveen, 2006), which concerns the philosophy-inspired design of a learning environment about the classes of vertebrate animals. The learning environment is addressed to primary school students, and in this case study we implemented and evaluated its first version. The implementation was carried out by the first author in three 1-1.5 hour sessions that took place in three consecutive school days. The evaluation was carried out through a pre/post questionnaire with open-ended items that students had to fill in individually. The questionnaire was first piloted with students of similar profile and the feedback was used for elaborating the initial phrasing or format of the items.

The participants

The participants of the case study were 19 fifth graders (8 girls/11 boys, age 10-11), who were attending a public school in a semi-urban area of Patras with medium/high socio-economic status. They were selected conveniently (Creswell, 2012) since their teacher volunteered to facilitate our study. Before starting the procedure, the first author visited children's school so that she could meet them, inform them about the study, and ask for their own assent to participate. The children were already familiar with group-work, as well as with vertebrate animals since they had the chance to discuss about them at several occasions in the previous school years.

The learning environment

Taking into account constructivism (Driver, Asoko, Leach, Scott & Mortimer, 1994) as well as several mechanisms of concept formation suggested by relevant philosophical theories such as the family resemblance inspired theories or the classical one (Gasparatou & Ergazaki, 2016; Murphy, 2002), we designed the first version of our learning environment. This consists of seven teaching-learning activities that aim at actively engaging students with class-based groupings of vertebrates with different categorization strategies. Using the strategies suggested by the *family resemblance inspired theories*, children were invited to think about vertebrates (a) by comparing new items with examples of each vertebrate class (*session 1*), and (b) by making lists of family resemblances *(session 2)*. Then, using the strategies the *classical theory* implies, children were encouraged (c) to make inferences about which of these resemblances are more usual and/or important for each vertebrate class (*session 2*), and (d) deduce the classes' 'key features' in order to differentiate between them (*session 3*). In sum, children had the chance to employ different categorization strategies throughout the sessions, like they do in everyday life.

In more detail, the participants were divided in five mixed-level groups of 3-6 members and collaborated in all three sessions. *Session 1* (activity 1.1) was based on a scenario about five small suitcases, each having cards depicting animals of one vertebrates class. When cards fell off and got mixed, only two per suitcase remained where they should be. Each peer-group had to focus on one suitcase (e.g. 'the bird suitcase'). In a whole class-discussion, peers were shown one by one the cards that fell off all the suitcases and had to compare them to the two cards still inside their group's suitcase, in order to decide whether each card should go or not to their suitcase and why. In *session 2*, each peer-group was given a different suitcase along with a *'features' list'* of the corresponding class. Students had to identify how many members of the class had these features, by choosing between *'all', 'some',* or *'none' (activity 2.1).* Then *(activity 2.2),* peer-groups exchanged suitcases, were given 'animal-cards', 'features-cards' and *'all'*-/*'some'*-/*'none'*-cards, and they were asked to use them for creating *true* phrases about the depicted animals (e.g. *'some birds fly'*; '*no reptile has feathers'*). Finally, they went through the process of deciding which card should go to which suitcase once more, but this time *not* by '*comparing to the class's exemplars'* like before, but by using *'features' lists' (activity 2.3).* In *session 3,* students had to compare the five lists and reject the features they had in common, in order to come up with the *'key features'* of each class *(activity 3.1).* Then *(activity 3.2)* were asked to identify the class of unknown animals by using a list of key/non-key features given to them. Finally, they had to decide how to create 'suitcase-tags' considering the strategies they tried for putting the cards back in place *(activity 3.3).*

The pre / post questionnaire

The pre/post questionnaire consisted of six open-ended items, but here we are concerned only with three of them. The first two items aimed at testing how students' groups of vertebrates may differ from the biological ones and why. Item 1 was based on a scenario about a five-hall museum. Each hall was already displaying two animal exhibits (hall 1: fox, squirrel; hall 2: eagle, sparrow; hall 3: snake, lizard; hall 4: frog, toad; hall 5: sea bream, sole), which belonged to the same vertebrate class, although this information was *not* given to the students. At some point, someone donated to the museum sixteen, new animal exhibits (bear, tiger, koala, dolphin, whale, bat, peacock, ostrich, penguin, crocodile, salamander, ray, seahorse, shark, swordfish, eel) and students, who had pictures of the animals at their disposal, were asked to distribute them all to the five halls. Justifying *why* they chose to configure the halls as they did, was required from them in item 2. Finally, the aim of item 3 was to test students' ability to distinguish between features that characterize *all* the members of a vertebrate class from features that characterize only *some*. Students were given 10 propositions, two per class, and they had to fill them in with a suitable quantifier (*'all'* or *'some')*. For instance, *'...... birds can fly'*, *'...... mammals have fur'* and so forth.

The analytic procedure

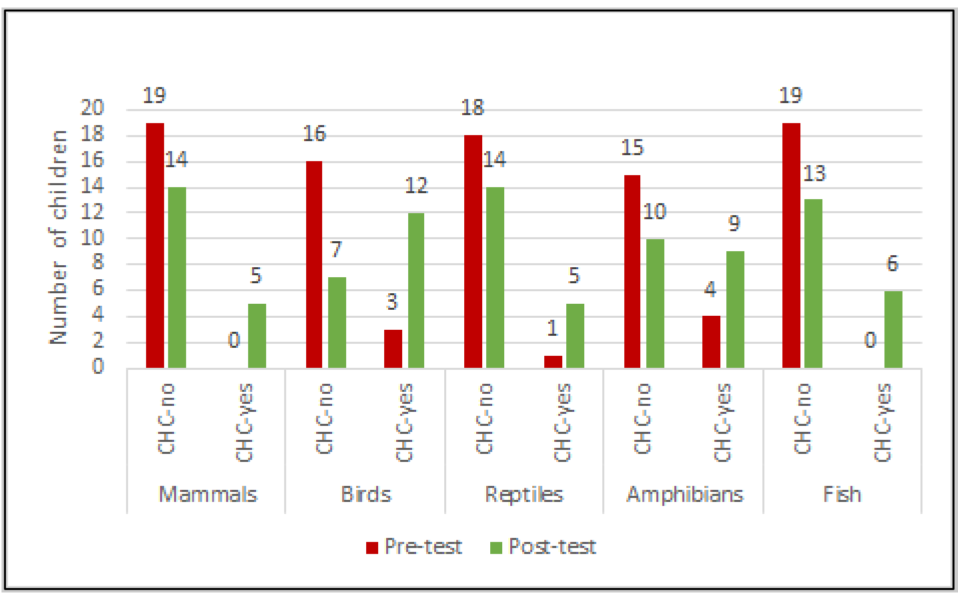
Students' responses to the items of the pre/post questionnaire were transcribed and prepared for coding in *NVivo*. Item 1 responses about the configuration of the museum halls with the new exhibits was coded according to whether each hall was configured as a *'class-hall'* or not. So, we created an 'NVivo-attribute' per hall, we gave it the 'values' *'class-hall configuration: yes'* or *'class-hall configuration: no'* and we coded accordingly. In order for the first 'value' to be attributed to a response, students should have configured the hall by displaying in it (a) *all* the new exhibits that belong to the same class with the two already there, and (b) *no*ne that belongs to a different one. Responses that didn't meet these two requirements *at the same time*, were given the value *'class-hall configuration: no'*. Item 2 responses about *why* students chose to configure each hall as they did, were coded as *'naive', 'transitional'* and *'informed*'. Responses that justified the configuration of the museum-halls by appealing to the animals' class and/or the class's key features, were coded as *'informed'*: [I put them together in this hall] *'because this will be the hall of mammals'* and/or *'because they all have fur'.* Responses that did not appeal to anything of the above, were coded as *'naive': 'They go together because they are dark creatures'.* Responses with *both* an *'informed' and* a *'naive'* part, were coded as *'transitional': 'Together because they're reptiles and they sneak'.* Item 3 responses were coded with regard to how many propositions per vertebrate class were filled in with the appropriate quantifier *('all' or 'some')*. So, we created an 'NVivo-attribute' for each vertebrate class which we called *'correct quantifier'* (in short *'CQ'*) and since children had to fill in two 'same class'-propositions, we gave the attribute the 'values' *'CQ_0', 'CQ_1', 'CQ_2',* and we coded accordingly. The coding of all items' responses was performed independently by two of the authors with a satisfactory agreement.

RESULTS

Configuration of the museum halls - item 1

Analyzing students' pre/post responses about how they would configure the five museum halls by distributing to them the new animal exhibits, showed that they made progress. In the post-test, the number of students who came up with *'class-halls'* ('*class-hall configuration: yes'* or *'CHC_yes'* in short) was always higher than in the pre-test, whereas the number of students who didn't ('*class-hall configuration: no'* or *'CHC_no')* was always lower than in the pre-test (Figure 1).

FIGURE 1



Class-hall ('CHC_yes') and non class-hall ('CHC_no') configurations in the pre/post-responses to item 1

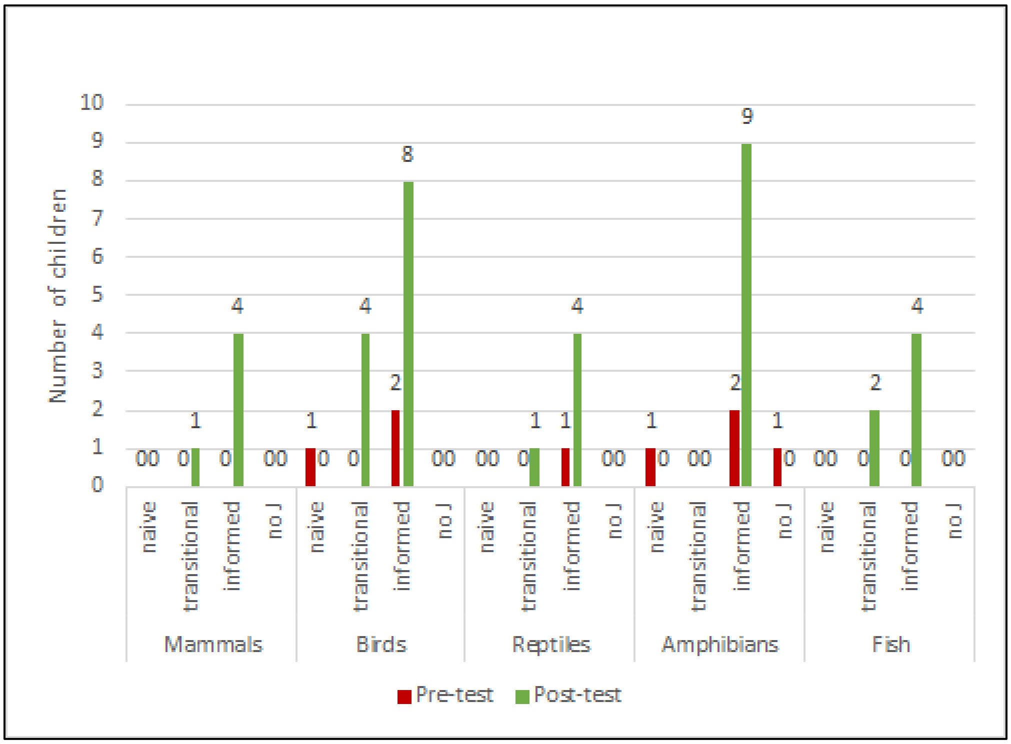
More specifically, in the case of birds, the post-number of students with *'CHC_yes'* was much higher than the pre-one (12/19 *vs.* 3/19), and the post-number of students with *'CHC_no'* was much lower than the pre-one (7/19 *vs.* 16/19) (Figure 1). The results about mammals, reptiles, amphibians and fish were slightly different: the post-number of students with *'CHC_yes'* was higher than the pre-one (mammals: 5/19 *vs.* 0/19, reptiles: 5/19 *vs.* 1/19, amphibians: 9/19 *vs.*

4/19, fish: 6/19 *vs.* 0/19), whereas the post-number of students with *'CHC_no',* although lower than the pre-one, remained still rather high (mammals: 14/19 *vs.* 19/19, reptiles: 14/19 *vs.* 18/19, amphibians: 10/19 *vs.* 15/19, fish: 13/19 *vs.* 19/19) (Figure 1). What follows is examples of '*non class-configured*' halls: hall 1- new exhibits: '*bear, tiger, koala, bat, dolphin, whale, shark' (post-test);* hall 5 (fish) - new exhibits: *'ray, eel, swordfish, hippocampus, penguin, dolphin, whale, shark'* (pre-test).

Justifications about the configuration of the museum halls - item 2

The analysis of students' pre/post justifications about how they would configure the museum halls by distributing the new animal exhibits to them, showed progress as well. Not only *more* students came up with *'class-hall'* configurations *('CHC_yes')* in the post-test, as already shown, but they also provided *'informed'* or *'transitional'* justifications and totally avoided *'naive'* (Figure 2).

FIGURE 2

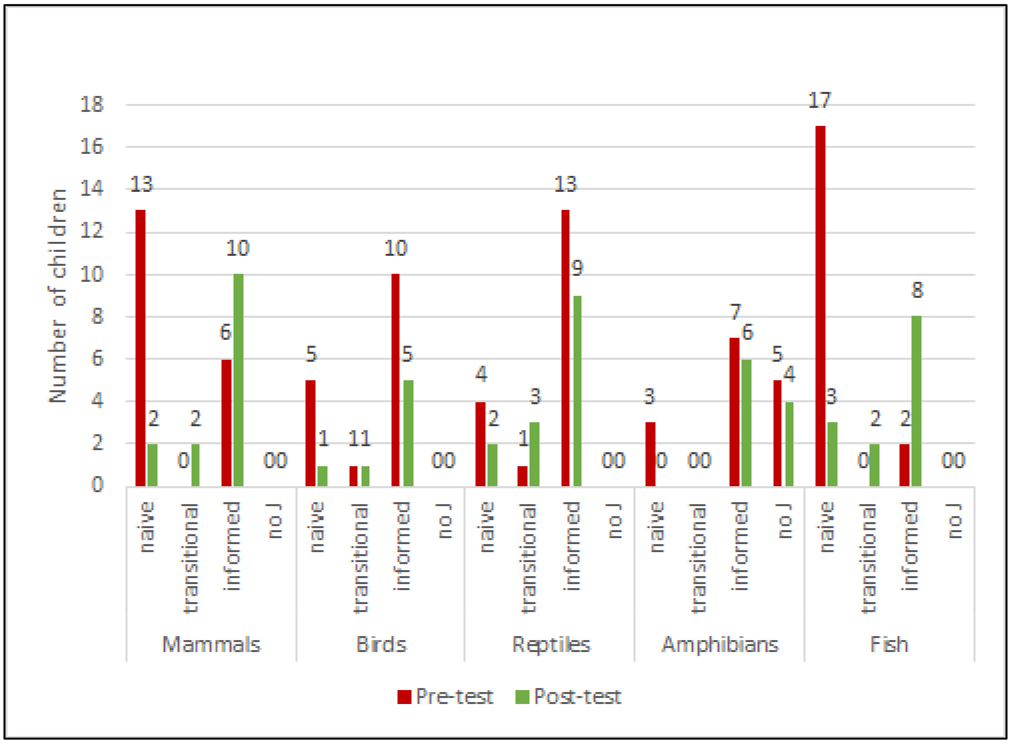


Justifying class-hall configurations ('CHC_yes') in the pre/post-responses to item 2

In the case of mammals, birds, reptiles and fish, all students with *'class-hall'* configurations justified them *mostly* in *'informed'* ways (mammals: 4/5, birds: 8/12, reptiles: 4/5, fish: 4/6) and none of them in *'naive'* (mammals: 0/5, birds: 0/12, reptiles: 0/5, fish: 0/6). In their own words, students configured, for instance, hall 2 by distributing to it all the new bird-exhibits and none non-bird *'because this is the group of birds'* (informed; post-test); '*because they are all birds and because they all have wings'* (transitional; pre-test); '*because they can fly'* (naive; pre-test). Moreover, in the case of amphibians, all students justified their post *'class-hall'* configurations *exclusively* in *informed'* ways (9/9). In their own words, students configured 'hall 4' by distributing to it all the new amphibian-exhibits and none non-amphibian *'because all these* *animals are amphibians; they have smooth and wet slippery skin, in the beginning of their life they breathe with gills and later on they breath with lungs'* (informed, post-test); *'because they live in similar places and they have similar bodies'* (pre-test, naive).

Concerning the *'non class-hall'* configurations, we note that not only *less* students came up with these *('CHC_no')* in the post-test, but they also provided mostly *'informed'* or *'transitional'* justifications and rarely 'naive*'* ones (Figure 3). In all five cases, all students with *'CHC_no'* gave much more *'informed'* and *'transitional'* justifications than 'naive' (mammals: 12/14 vs 2/14, birds: 6/7 vs 1/7, reptiles: 12/14 vs 2/14, amphibians: 6/10 vs 0/10, fish: 10/13 vs 3/13). In their own words, students configured, for instance, hall 1 with *'bear, tiger, koala, bat, whale' 'because these are the group of mammals and nurse their young'* (informed; post-test), or with '*bear, tiger, koala, penguin'* '*because those animals found in forests should go to hall 1'* (naive; pre-test).

FIGURE 3



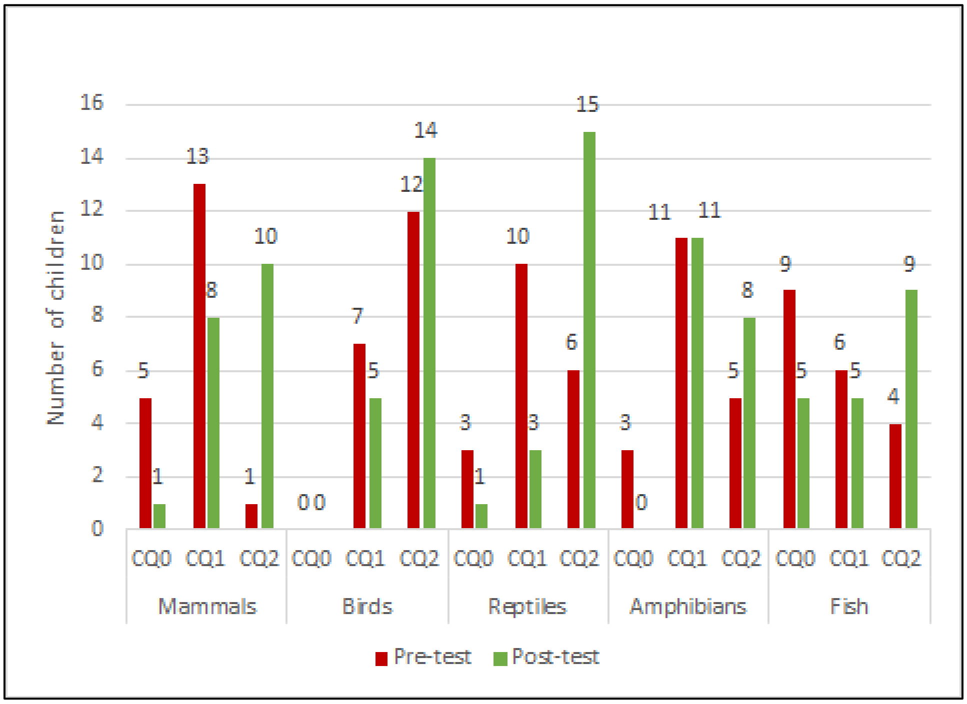
Justifying non class-hall configurations ('CHC_no') in the pre/post-responses to item 2

Use of the quantifiers 'all' and 'some'- item 3

The analysis of students' pre/post-use of the quantifiers *'all'* or *'some'* with regard to the members of vertebrate classes, showed that they made progress after their engagement with the learning environment (Figure 4). Concerning mammals, we found that in the post-test the number of students who used the appropriate quantifier either in one proposition *('CQ_1)* or in none *('CQ_0)*, decreased ('8/19 *vs.* 13/19' & '1/19 *vs.* 5/19', correspondingly), whereas the number of students who used the appropriate quantifier in *both* the propositions they had to fill in *('CQ_2),* increased rather remarkably (10/19 *vs.* 1/19) (Figure 4). This was also the case for reptiles and fish. In both cases, the number of students who used, in the post-test, the appropriate quantifier in *both* propositions *('CQ_2)*, increased rather remarkably ('*CQreptiles'_2:* 15/19 *vs.* 6/19;

'CQfish_2': 9/19 *vs.* 4/19), whereas the number of students who did so in just one proposition *('CQ_1)* or even none *('CQ_0)* decreased (Figure 4).

FIGURE 4



Use of the quantifiers 'all' and 'some' in the pre/post-responses to item 3

Concerning birds and amphibians, the number of *'CQ_2'*-responses showed a slight increase in the post-test. In the case of birds, in which there were no *'CQ_0'*-responses either in the pre- or in the post-test, the slight increase in the number of '*CQ_2'* post-responses (14/19 *vs.* 12/19) derived from the slight decrease in the number of *'CQ_1'*ones (5/19 *vs.* 7/19) (Figure 4). In the case of amphibians, in which the number of *'CQ_1' pre/post*-responses didn't change (11/19 *vs.* 11/19), the slight increase in the number of '*CQ_2'* post-responses (8/19 *vs.* 5/19) derived from the maximum possible decrease in the number of *'CQ_0'*ones that were totally eliminated (0/19 *vs.* 3/19).

DISCUSSION

According to the results, students *did* make progress with grouping vertebrate animals in *class*-groups. Class-groupings, as explored through the supposed configuration of five museum halls as class-halls or not, became much more popular after the implementation of the learning environment. However, many students weren't able to come up with class-groupings for any vertebrates except birds. So, although this might have to do with the rather strict way we defined *'class-hall'* configurations in our analysis (a 'museum hall' was considered as 'class configured', if it included *all* the new animal exhibits of the class *and none* of other classes), it seems that there *is* room for improvement in the learning environment.

Moreover, not only *more* students came up with class-groupings in the post-test, but they also provided *'informed'* or *'transitional'* justifications exclusively. More interestingly, *less* children came up with non class-groupings, and even them *mostly* provided *'informed'* or *'transitional'* justifications. So, even though they didn't come up with fully class-configured halls, the fact that they used mostly *'informed'* and *'transitional'* justifications for their groupings (i.e. they appealed to a class and/or its key features) may indicate that they *did* wish to come up with class-configured halls, but they just lacked some knowledge about specific animals and their classes. In other words, it seems that they grasped the need to move to a biology-informed categorization strategy that involves class identification or 'key-features', but they were unable to perform it adequately yet.

Finally, students also improved their use of specific quantifiers (*'all', 'some'*) with regard to vertebrates classes. In the case of mammals, reptiles and fish, the consistent use of the appropriate quantifier *('CQ_2')* increased remarkably, whereas in the case of birds and amphibians it showed a slight increase. In the case of birds, this *slight* post-increase may be linked with the high number of '*CQ_2*' responses already in the pre-test. Finally, in the case of amphibians it seems that students' knowledge, although initially promising (high pre-*'CQ_1'*), just wasn't developed enough.

In sum, the first version of the learning environment seemed to work quite well but it also needs further elaboration. The overall rationale of inviting children to play with different categorization strategies when grouping vertebrate animals, and deduce some basic biological categorization principles step-by-step, seemed to pay off. LE1 relied, up to one point, on children's ability to form categories in flexible ways and tried to guide them to understand how we usually think when trying to make sense of the biological world. Any further development of the learning environment then, should be consistent with this rationale and include even more activities that facilitate the employment of different categorization strategies, building on children's ability for reflection and renegotiation, rather than working against it.

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REFERENCES

Akker, J. V. D., Gravenmeijer, K., McKenney, S., & Nieveen, N. (Eds.). (2006). *Educational Design Research*. Oxon, England: Routledge.

Allen, M. (2015). Preschool children's taxonomic knowledge of animal species. *Journal of Research in Science Teaching, 52*(1), 107-134.

Barman, C. R., Stein, M., McNair, S., & Barman, N. S. (2006). Students' ideas about plants & plant growth. *The American Biology Teacher*, *68*(2), 73-79.

Creswell, J. W. (2012). *Educational research: Planning, conducting, and evaluating quantitative and qualitative research* (4th ed.). Boston, MA: Pearson.

Driver, R., Asoko, H., Leach, J., Scott, P., & Mortimer, E. (1994). Constructing scientific knowledge in the classroom. *Educational Researcher*, *23*(7), 5-12.

Earl, D. (2006). Concepts and Properties. *Metaphysica*, *7*(1), 67-85.

Ergazaki, M., Gasparatou, R., & Valanidou, E. (2018). Young children's reasoning when sorting pictures and objects. In N. Gericke & M. Grace (Eds.), *Volume of selected papers from ERIDOB 2016: Challenges in Biology Education Research* (pp. 199-215). Karlstad, Sweden: University of Karlstad.

Gasparatou, R., & Ergazaki, M. (2016). Could philosophy inform biology education? *Educational Journal of the University of Patras UNESCO Chair*, *3*(2), 29-35.

Kattmann, U. (2001). Aquatics, Flyers, Creepers and Terrestrials - students' conceptions of animal classification. *Journal of Biological Education*, *35*(3), 141-147.

Kenny, A. (2010). Concepts, brains, and behaviour. *Grazer Philosophische Studien*, *81*(1), 105-113.

Markman, E. M. (1989). *Categorization and naming in children: Problems of induction.* Cambridge: The MIT Press.

Murphy, G. L. (2002). *The big book of concepts.* Cambridge, MA: MIT press.

Natadze, R. G. (1963). The mastery of scientific concepts in school. In B. Simon & J. Simon (Eds.), *Educational Psychology in the USSR* (pp. 192-197). London: Routledge and Kegan Paul Ltd.

Trowbridge, J. E., & Mintzes, J. J. (1988). Alternative conceptions in animal classification: A cross-age study. *Journal of Research in Science Teaching*, *25*(7), 547-571.

Wittgenstein, L. (1958). *Philosophical Investigations*. New York: MacMillan.

Yen, C. F., Yao, T. W., & Chiu, Y. C. (2004). Alternative conceptions in animal classification focusing on amphibians and reptiles: A cross-age study. *International Journal of Science and Mathematics Education*, *2*(2), 159-174.