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Learning science in small multi-age groups: the role of age composition

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ABSTRACT
The present study examines how the overall cognitive achievements in science of the younger children in a class where the students work in small multi-age groups are influenced by the number of older children in the groups. The context of the study was early-years education. The study has two parts: The first part involved classes attended by pre-primary children aged 4-6. The second part included one primary class attended by students aged 6-8 in addition to the pre-primary classes. Students were involved in inquiry-based science activities. Two sources of data were used: Lesson recordings and children's assessments. The data from both sources were separately analyzed and the findings plotted. The resulting graphs indicate a linear relationship between the overall performance of the younger children in a class and the number of older ones participating in the groups in each class. It seems that the age composition of the groups can significantly affect the overall cognitive achievements of the younger children and preferentially determines the time within which this factor reaches its maximum value. The findings can be utilized in deciding the age composition of small groups in a class with the aim of facilitating the younger children's learning in science.

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KEYWORDS
Small multi-age groups; science learning; early-years science education; role of age in mixed-age grouping; learning science in small groups

Introduction

Students' learning through interacting with each other rather than only with their teacher is of much interest to educational researchers and practitioners; it is also a highly evaluated goal (Webb, 1989). The social skills of individuals allow them to participate in learning activities in small groups and learn from each other (Huber & Huber, 2007). Vygotsky (1978) suggested that children's knowledge and ideas develop through interactions with others. In his view social interactions with more capable peers play a key role in understanding the meaning of concepts, and thus in learning. To achieve this, students need a learning environment that promotes interactive learning processes, preferably from the lower grades of education (Huber & Huber, 2007). At the heart of this view of learning is the situation or context within which learning takes place. Taking into consideration

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that learning is a transactive phenomenon existing in situations created by the teacher, and that social interactions and skills allow individuals to benefit from the opportunities to learn from each other, the teacher can create environments in which students can collaborate with peers and adults (Hassard & Dias, 2009). Examples of such environments are small mixed-ability cooperative groups, the use of which is supported by extensive evidence from numerous studies (e.g. Blumenfeld, Marx, Soloway, & Krajcik, 1996; Gillies, 2003; Katz, 1995; Nastasi & Clements, 1991). Students in small heterogeneous groups help, share and support each other's learning as their members provide information, prompts, cues and encouragement in response to other children's needs (Gillies, 2003; Hassard & Dias, 2009). Often they are more aware of their peers' needs than their teachers, and can explain problems in a way that can be readily understood (Webb & Farivar, 1994). It has been found that children achieve more when they work together in small groups than they do in whole class, attain higher academic outcomes and are more motivated to achieve (Gillies, 2003; Lou et al., 1996).

Small cooperative groups are used in several countries across all levels of education, not only for supporting and improving students' learning, motivation and attitudes (Blumenfeld et al., 1996; Slavin, 1983), but also as a way of handling large classes (Slavin, 1983).

In science education, a large number of studies on instructional practices have given results showing the effectiveness of small groups of children of mixed abilities (Hassard & Dias, 2009). Hassard and Dias (2009) note that the term 'collaborative' emphasizes the importance of verbal communication between students during their interactions in a small group when they work on a specific task. Krajcik, Blumenfeld, Marx, and Soloway (2000) mention that one of the aims of collaboration and interaction is to build knowledge through talks and discussion. This collaboration also introduces the students to the 'language' of the discipline under study and to ways of knowledge acquisition.

While small-group-learning has a long history (Wagner, 1982), it is only in the last decades that researchers have studied the interactions within them that facilitate learning and the factors that lead to different patterns of interaction (Webb, 1989). One of these factors is the number of participants in a small learning group. Lou et al. (1996) have found that children's benefits from small-group work are contingent on group size and composition. Huber and Huber (2007) suggest that groups should comprise as many members as are still able to interact directly with each other. Another factor that has proved to be important is the age of the members of a small group. Furman, Rahe, and Hartup (1979) maintain that socialization in mixed-age groups serves children in many ways that same-age socialization does not, and note that mixed-age groups require accommodations between individuals whose developmental levels differ. It has been found that learning more usually takes place through the interactions of older children with younger ones.

Katz (1995) notes that mixed-age grouping, especially in early childhood settings, is intended to increase the heterogeneity of the group so as to capitalize on the differences in knowledge, ability and experience of the children. The study suggests that in a mixed-age group younger children are capable of participating in and contributing to more complex activities than they could initiate if they were by themselves. Katz (1995) also reports that research on social benefits indicates that children very early associate different expectations with different age groups: for example, younger children assign older ones instructional, leadership, helpful and sympathizing roles, whereas older

children see younger ones as needing help and instruction. With regard to intellectual benefits, she notes that cognitive development studies show that cognitive conflict occurs when the interacting children have different levels of understanding. She also observes that in a mixed-age group a teacher is more likely to identify differences within each individual child as well as between the children.

The following findings are also of importance: (a) children prefer to be taught by children older than themselves (Allen & Feldman, 1976); (b) older children are more effective models than younger children (Peifer, 1971) and (c) reciprocal imitation is more characteristic of children's interactions with older children than with younger children (Roberts, 1980; Thelen & Kirkland, 1976).

Modeling is the process by which younger children pick up behaviors they observe in older ones. If older students and younger students work closely while engaging in learning activities, the younger students will seek to imitate the behaviors modeled by the older ones (Merrick, 1996). Younger children will imitate both academic and social behaviors demonstrated by older children. Merrick (1996) maintains that nothing is more interesting to a child than another child who has the skills that he/she would like to acquire. In addition to this unintended natural modeling, older students can also provide direct instruction to younger ones. Goularte (1995) notes that when one student shows another how to do a task, he/she introduces the concept and allows the other to practice the skill and develop nurturing behaviors.

In the present work, we are concerned with the learning in science of children in early-years education (4–8 years of age). Two previous studies (Kallery, 2011, 2015) of the science-related performance of children aged 4–6 who worked in small multi-age groups during inquiry-based science activities have documented high overall learning achievements in the children participating in the activities.

Based on the issues outlined above, in the present study we investigate the overall performance in science of the younger children in a class where they participated in small mixed-age groups, in an effort to see whether this factor is influenced by the proportion of older children in the groups. The present study allows us to quantify the role of age composition in small science-learning groups. These findings can be very useful in deciding how to group children in a class to facilitate the younger ones' learning in science.

The question leading our research is:

- How do the overall cognitive achievements in science of the younger children in a class where the students work in small multi-age groups change in relation to the number of older children participating in those groups?

Context

The present study was conducted in Greece and involved students from the two lowest levels of education, pre-primary and primary. In the Greek educational system pre-primary and primary schools operate separately, with different daily and weekly timetables. The composition of the classes is also different. Pre-primary classes are mostly multi-age, and are usually attended by an average of 20 children aged 4–6. At this level, the age groupings are: 4–5 = pre-kindergarteners (PKs) and 5–6 = kindergarteners (Ks).

There are a few cases, depending on enrollment, where some classes are composed of children of the same age group, that is, either only of pre-kindergarteners or only of kindergarteners. Pre-primary teachers are required to implement the National Curriculum for Pre-primary Education, which proposes two kinds of activities for the children: 'free' activities, which are chosen and carried out by the children themselves without the direct involvement of the teacher, and 'teacher-organized' activities, which are planned and organized by the teacher according to the objectives that have to be met. Teachers can organize activities on topics relating to phenomena that children encounter in everyday life or topics arising out of the children's interests or questions. If the children's interests do not bring up issues which the teacher considers important and appropriate for pre-primary children, she/he can design activities to meet a selected objective, choosing the topic, content and instruction materials accordingly. Domains from which the topics for activities can be drawn include physics and outer space. The physics curriculum proposes topics relating to concepts such as weight, sound, light, motion, temperature and magnetism, basic characteristics of materials and properties of matter such as floating/sinking, melting, dissolving in water, etc. Space-related topics include Earth's sphericity and motions and the phenomenon of day and night. The choice of classroom organization, instructional approach and topics for the 'teacher-organized' activities is left up to the teacher.

Primary school starts at age 6 and is of six years' duration. The classes are composed of children of the same age group (first grade 6–7 years of age, second grade 7–8, etc.). In primary school, the teaching of topics related to physics and outer space starts systematically at the fourth grade. However, in a framework called 'Flexible Zone of Activities,' the National Curriculum for Primary Education provides opportunities for innovative pedagogical and didactical approaches (e.g. classes of children from different grades) and allows the introduction of concepts and phenomena that complement those introduced through the formal program and enhance the basic skills that the formal activities proposed by the curriculum are expected to develop. These may be related to experiences that children commonly encounter in everyday life. Teachers may also identify topics that they consider to be interesting, important and appropriate for children of specific ages, which may not be included in the tight weekly timetable of the school program. They can, in other words, select objectives and design activities, choosing the topic, content and instruction materials accordingly.

Design of the study

The research reported in this paper is a small-scale exploration study designed to be carried out in real classroom settings, in two parts (Part 1 and Part 2). Four schools participated in each part of the study (one class from each of the schools). The schools were from four different urban areas of central northern Greece and were attended by students of the same socioeconomic background.

The two parts of the study were carried out two years apart, so that the pre-primary students of the first part would have moved on to primary school. The pre-primary classes of the second part of the study were therefore composed of an entirely new group of children, who had not attended science activities before. Additionally, the lower primary children involved in Part 2 of the study had not previously attended

science activities either in pre-primary education or in primary school and had not previously been involved in any 'Flexible Zone of Activities'.

In all the classes, the teachers implemented the same inquiry-based science activities (same content, instruction materials and instruction approach) which were developed specifically for pre-primary and early-primary education with topics from physics and outer space (Kallery, 2011, 2015). Inquiry was chosen as the approach to science activities as it is considered to make learning more meaningful and supports the development of a more appropriate understanding in science (e.g. European Commission, 2007; Hassard & Dias, 2009). Activities were hierarchically sequenced in order to support construction of meaning. Implementation began in October and ended in May.

In the activities children worked in groups. Traditionally, group work involves four to six students (Huber & Huber, 2007). In our study, groups of five students were formed. We felt that this was a number that provides good opportunities for interaction between members and allows for different age combinations within the group. Since each child has a probability of interacting with each of the others in the group, we assumed that when there are fewer younger than older children in a group, each of the younger children will have a higher probability of interacting with an older one. Thus, for the purpose of our study, we varied the number of younger children in the groups in each of the classes, keeping the total size of each group at 5 (all groups in a class had the same age composition).

The teachers whose classes took part in the study had been members of a work group for many years (average 11 years), facilitated by a researcher in science education with a background in physics (first author of the present paper). All of the teachers had long experience in teaching science at the corresponding levels of education and, as members of the above-mentioned work group, had participated in the development of the instruction material used in science activities (Kallery, 2016). Nonetheless, before implementing the activities, the teachers and the researcher discussed the content and methodology of the activities in group meetings. Also, all of them used the same teacher's guide during the implementation. These teachers, being members of the above-mentioned work group for many years, had participated in research projects several times and were very experienced in making observations, recording data and performing student assessments during actual classroom work as well as post-instructional assessments.

Description of the parts of the study

Part 1

The first part of the study involved only pre-primary children. Three of the four classes participating in Part 1 comprised children of the age groups 4–5 and 5–6 years; the fourth had only children aged 4–5 (pre-kindergarteners). The age composition of the groups depended on the number of children of each age group enrolled in the school. Thus, in the school attended only by children of the age group 4–5, the groups were composed only of pre-kindergarteners and constituted the control class. In the school with more pre-kindergarteners than kindergarteners, the groups were composed of three pre-kindergarteners and two kindergarteners. In the other two schools, there were more kindergarteners than pre-kindergarteners and the groups were composed in one case of

two pre-kindergarteners and three kindergarteners and in the other of one pre-kindergartener and four kindergarteners. In two of the schools, as the number of children in the class was not a multiple of five, one additional group of six students was formed in each of them.

Part 2

In Part 2 of the study, which as mentioned earlier took place two years after Part 1, there was no class exclusively of pre-kindergarteners; instead, a class from primary school was included. This class was composed of three groups of children from the age groups 6–7 and 7–8 (i.e. from the first and second grades of primary school), who participated in the 'Flexible Zone of Activities.' The age composition of these groups was two students from the age group 6–7 and three students from the age group 7–8. The primary teacher who organized this class was the headmistress of the school and taught in its first and second grades, and had the opportunity to form the above-mentioned groups. The reason for including primary students in the study was to find out whether the same pattern (model) of performance of the younger children would be repeated when students at a higher level but still within the early-years age bracket (4–8) were taking part. The rest of the classes participating in Part 2 were the new pre-primary classes of the same teachers who took part in Part 1. The age composition of the groups in the three pre-primary classes was one kindergartener and four pre-kindergarteners, two kindergarteners and three pre-kindergarteners, and four kindergarteners and one pre-kindergartener. In one class, where the number of the students was not a multiple of five, one group had only four students.

Data collection

Since very young children may act and perform quite differently during class work and post-instructional assessment, we considered that the results would be more representative if their performance was assessed on the basis of a combination of data from both sources. Data were thus derived from:

a) *The post-instructional assessments of the children*. In order to evaluate how each team member has benefited personally with regard to knowledge and understanding of the concepts and phenomena under study (Huber & Huber, 2007), the assessments were carried out individually. Concept cartoons were used for physics (Kallery, 2015) and specially designed post-instructional tasks for outer space (Kallery, 2011). Two representative test items are presented in the Appendix. In both types of assessments, the children were asked to justify their responses or choices. Post-instructional assessments started in January, after the children had completed the first cycle of activities, and were carried out monthly until May.
b) *Teachers' recordings made during all the stages of implementation of the activities from October to May*. Each teacher audio-recorded her lessons. An average of 95 hours for each part of the study was recorded and transcribed into protocols. Audio-recordings documented all the verbal exchanges that took place in the classroom in the course of the activities. The transcribed data were supplemented by the teachers with field

notes, that is, with data that could not be provided by the audio-recordings. The final protocols were accompanied by photographs and by children's drawings and representations as well as their verbal explanations of their drawings. The teachers produced a separate protocol for each of the activities.

Data analysis

Both sets of data were analyzed in group sessions in which all the teachers participated, along with two research colleagues, specialists in science education, one of whom was the first author of the present paper, who was the best placed to understand the context within which the program activities had unfolded.

Analysis of the post-instructional assessments

Before the analysis of the younger children's responses to the post-instructional assessments described above, the group defined the rubrics (correct answers and reasoning) on which the analysis would be based. The analysis classified each individual child's responses as either 'acceptable' or 'non-acceptable'. Acceptable responses were both correct and correctly reasoned. Non-acceptable responses were those that were either incorrect or incorrectly reasoned.

Acceptable responses were assigned the value 1 and non-acceptable ones the value 0, and an average grade was produced. The success rate of the younger students in each class for a specific evaluation task was then calculated. From these findings, their average performance for each month of the evaluation was estimated.

Analysis of classroom data

The protocols were first examined for clarity. An average of 80 hours was chosen for analysis in each part of the study.

The analysis of the lesson protocols sought to identify younger children's responses and justifications to questions and queries posed by the teachers during group work, answers to peer questions and expression of knowledge.

For each case, as in the analysis of the post-instructional assessment, what was considered correct and incorrect was again decided by the group, and the classification as 'acceptable' and 'non-acceptable' was done on the same basis as in the individual post-instructional assessment.

In all cases, as above, the values 1 and 0 were assigned for 'acceptable' and 'non-acceptable' responses and an average grade was produced. The success rate of the younger students in each class during group work was then calculated. From these findings, the average performance of these children for each month from October, when implementation of the actives began and the children started working in groups, to May, when they stopped, was estimated. The final value of the children's performance was found by calculating the average of the children's performance in the classroom and in the post-instructional assessments for each month from January to May.

Results

Part 1

Results were plotted for each of the classes. Two representative graphs of these are shown in Figures 1 and 2, where E_p is the performance of the younger children (pre-kindergarteners). In these figures, graph B represents classroom data, C the post-instructional assessments and D represents the average of B and C. The maximum value the children's performance reached and the point at which it stabilized (i.e. it presents small fluctuations with regard to the previous months) are shown.

These graphs also provide information on the length of the time it took for the younger children of each class to reach their maximum performance level, starting from the time they began to collaborate with the older children in science activities. These findings were plotted and yielded the graph shown as Figure 3 (with correlation coefficient $R = -0.984$)[1] where (n_k) is the number of older children participating in the groups of each of the classes.

Using graph D, the average performance for the younger children in each of the classes for the months January to May and the uncertainty ranges of the average were calculated. Plotting these values gave the graph in Figure 4 (with correlation coefficient $R = 0.983$), which represents the performance E_p of the younger children in relation to the number of older children n_k that participated in the groups of each of the classes.

These results were corroborated, with small variations (4% and 1%, respectively), in the two six-member groups (formed in the two classes where the number of students was not a

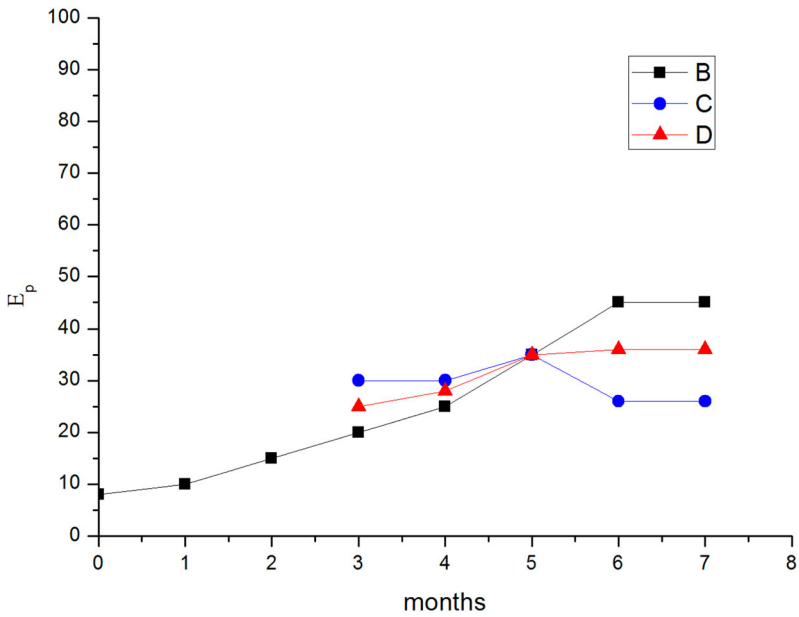

Figure 1. Performance (E_p) by month of the students of the class composed only of pre-kindergarteners. Graph B represents classroom data, C the post-instructional assessments and D represents the average of B and C.

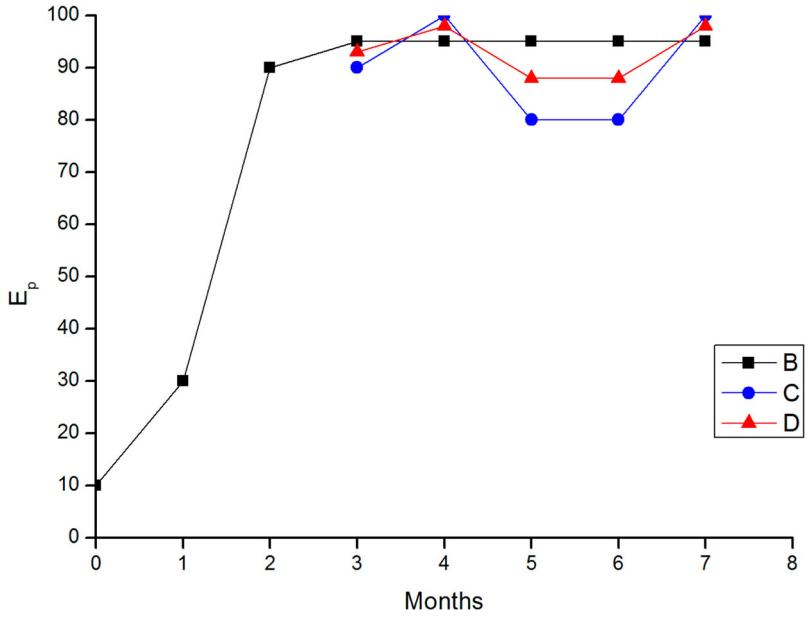

Figure 2. Performance (E_p) by month of the pre-kindergarteners in the class with groups composed of one pre-kindergartener and four kindergarteners. Graph B represents classroom data, C the post-instructional assessments and D represents the average of B and C.

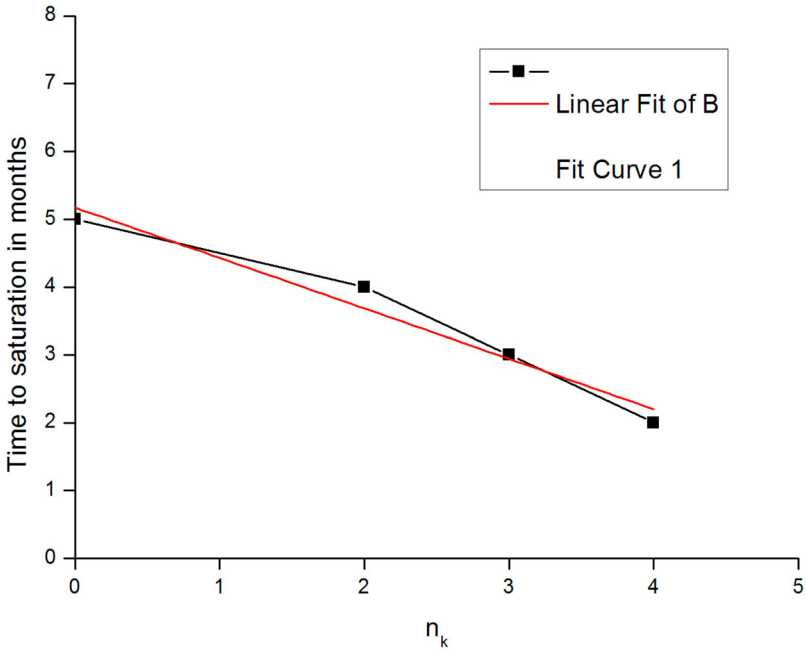

Figure 3. Time in months in which the younger children of each class reached their maximum performance in relation to the number of older children (n_k) participating in the groups of each of the classes.

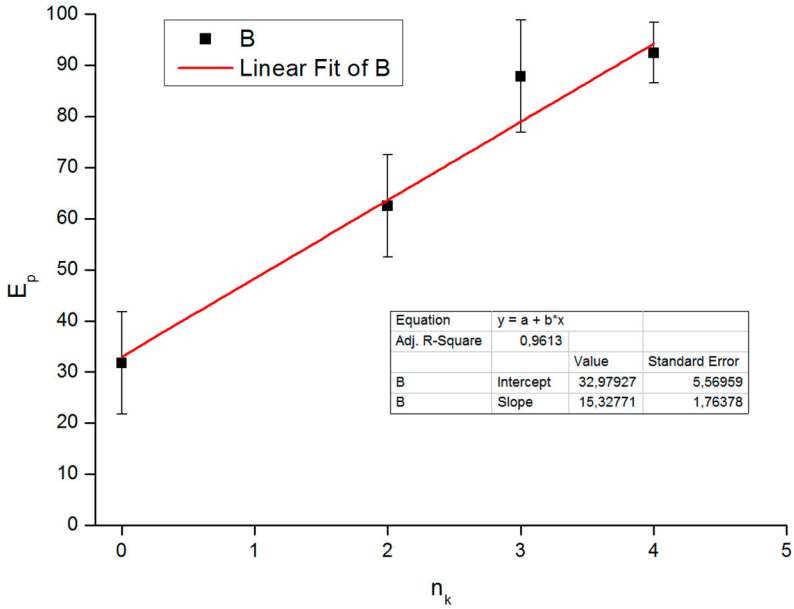

Figure 4. Performance (E_p) of the younger children of each class in relation to the number of older children (n_k) participating in the groups of each class.

multiple of five), which had different age compositions (four kindergarteners and two pre-kindergarteners, and two kindergarteners and four pre-kindergarteners).

The teachers' field notes and recorded observations about the younger children's performance over the months of the activities were illuminating. Below are some representative excerpts from the records of the teachers of two different classes, revealing the evolution of the children's achievements:

The teacher ('P') of the class where the groups had one pre-kindergartener and four kindergarteners wrote about the performance of the younger children in the groups:

> The first month, the month of adjustment and awareness, I did not observe anything interesting. After this month the little ones advanced rapidly, they went up literally like a bullet and stayed at this high level.

The teacher of the class with groups of three pre-kindergarteners and two kindergarteners wrote about the younger children's performance:

> The younger children were somehow lost for quite some time. Had no sense of what was going on. Their performance was minimal. February came and suddenly I realized that a sudden progress had happened.

The teachers' recorded observations were discussed in the group sessions, where they made additional comments providing more specific information about the differences in the children's performance, which were corroborated by the performance graphs. One example is the comment of the second teacher, who compared the progress made by the younger children in her class with that of the younger children in the first teacher's class:

They reached a pretty high level but definitely lower than what 'P' describes for her younger pupils.

Part 2

As in Part 1, the results were plotted for each of the classes. Three graphs relating to the performance of the younger children are presented below. Those in Figures 5 and 6 come from the evaluation of the pre-primary children, and the graph in Figure 7 from the evaluation of the primary school children. In all these graphs, E_p is the performance of the younger children. As in the graphs of Part 1, graph B represents classroom data, C the post-instructional assessments and D represents the average of B and C. The maximum value which the children's performance reached and the point at which it stabilized (i.e. it presents small fluctuations with regard to the previous months) are shown.

As in Part 1, these graphs also provide information on the length of time it took for the younger children in each class to reach their maximum performance, starting from the time they began to collaborate with the older children in science activities. These findings were plotted and yielded the graph in Figure 8 (with correlation coefficient $R = -0.979$) where (n_k) is the number of older children participating in the groups of each of the classes.

Again, as in Part 1, the average performance for the months January to May for the younger children of each of the classes as well as the uncertainty ranges of the average were calculated using graph D. Plotting these values gave the graph in Figure 9 (with

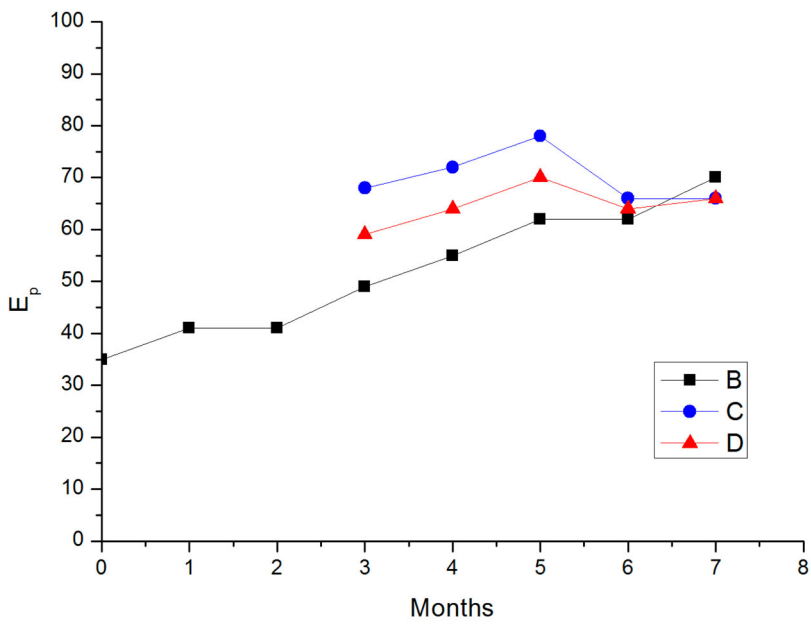

Figure 5. Performance (E_p) by month of the pre-kindergarteners of a class where the groups were composed of four pre-kindergarteners and one kindergartener. Graph B represents classroom data, C the post-instructional assessments and D represents the average of B and C.

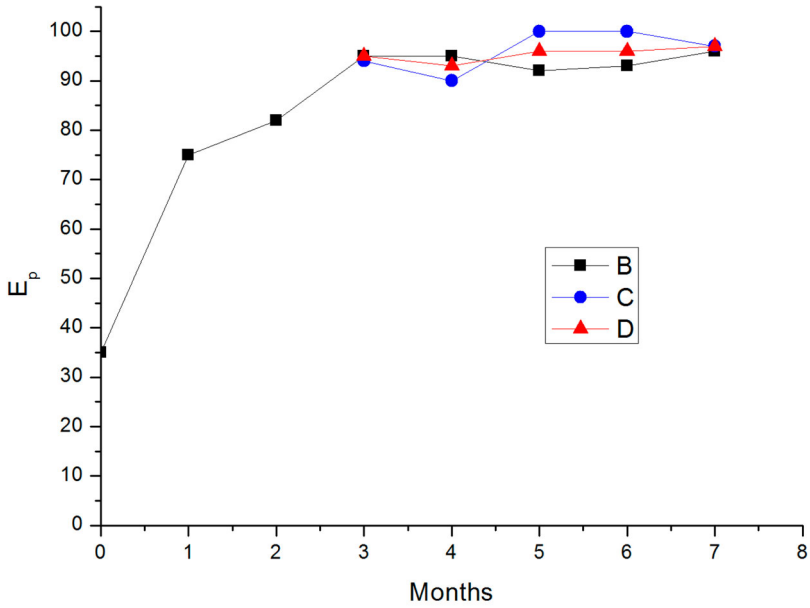

Figure 6. Performance (E_p) by month of the pre-kindergarteners of a class where the groups were composed of one pre-kindergartener and four kindergarteners. Graph B represents classroom data, C the post-instructional assessments and D represents the average of B and C.

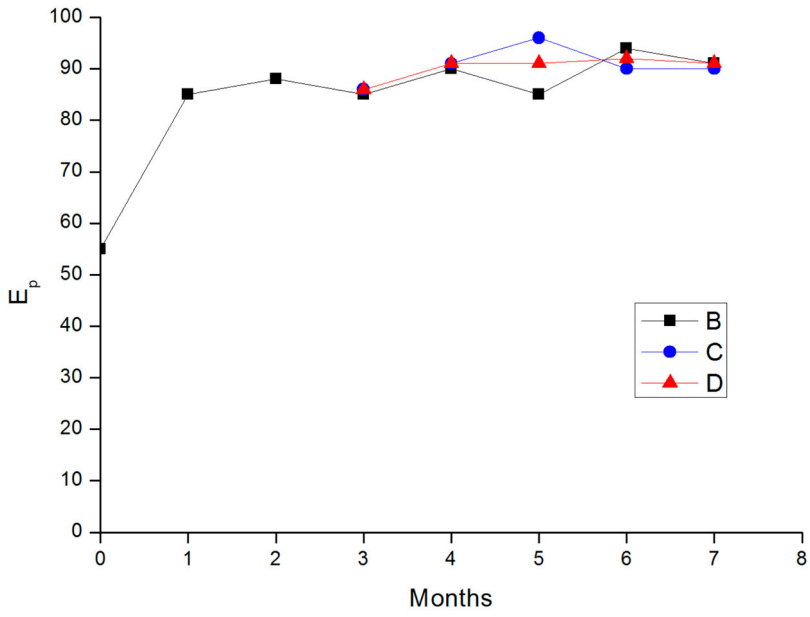

Figure 7. Performance (E_p) by month of the younger children in the primary class where the groups were composed of two students of age group 6–7 and three of age group 7–8. Graph B represents classroom data, C the post-instructional assessments and D represents the average of B and C.

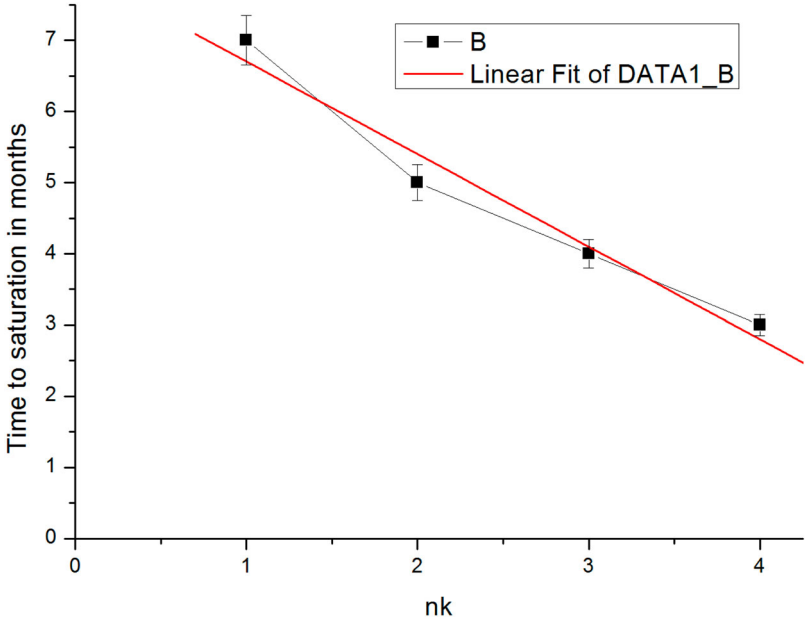

Figure 8. Time in months in which the younger children of each class reached their maximum performance in relation to the number of older children (n_k) participating in the groups of each of the classes.

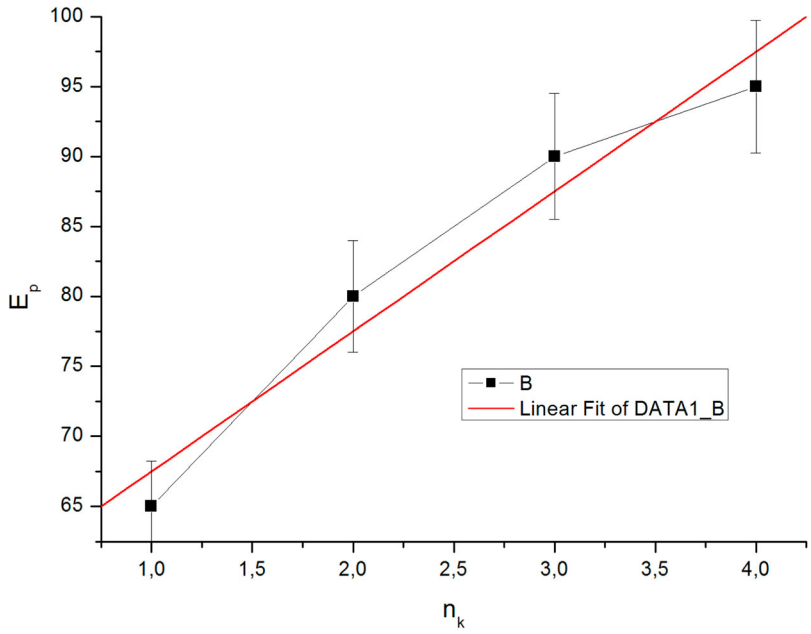

Figure 9. Performance (E_p) of the younger children in each class in relation to the number of older children (n_k) in the groups of each class.

correlation coefficient $R = 0.970$), which represents the performance E_p of the younger children in relation to the number of older children n_k in the groups of each of the classes.

These results were corroborated, with a very small variation (3%), in the four-member group that was formed in a class where the number of students was not a multiple of five, which had two kindergarteners and two pre-kindergarteners.

The pre-primary teachers' field notes and recorded observations about the younger children's performance over the months of the activities yielded findings very similar to those of Part 1. Observations for the younger primary students' cognitive achievements over the months of the activities were also recorded by the primary school teacher. Below are some of the most characteristic ones, revealing the gradual progress of her younger students:

> [In January]: The cognitive achievements of the young children in the classroom have now reached a high level. In the final evaluations also these children did very well!!
> [In April]: I am very impressed by the younger children's achievements in the cognitive domain. They have understood things so well that when another teacher came into the class they kept on asking him questions to see if he knew why a big ship does not sink and what the play dough does when put in water.

Other findings from the teachers' field notes

The analysis of the teachers' field notes also yielded information about the younger children's collaboration with the older ones in the group. Some excerpts from the teachers' records describing how these children's collaboration within the group evolved are presented below:

In Part 1 of the study, the teacher of the class with group composition three pre-kindergarteners and two kindergarteners wrote:

> For quite some time communication was not good. The younger children in the groups did not communicate with the older ones and they did not collaborate well. From February on things changed. Now when some members of the groups are absent we have problems – the rest cannot work without them.

The teacher of the class with group composition two pre-kindergarteners and three kindergarteners wrote:

> In the beginning, each of the younger ones was acting alone. No communication. After the adjustment period was over the older ones started to show the younger what to do. They were giving them advice and assigning them tasks such as for example to find specific materials and bring them to the group for work. This led to a great collaboration.

In Part 2 of the study, the observations reported by the pre-primary teachers relating to the younger children's collaboration were very similar to those of Part 1.

The primary school teacher, in her field notes, also described the primary school children's collaboration in the groups. Below is an excerpt from her records:

> With respect to the collaboration among the children, not much was achieved before the third lesson. During this period the children worked individually. A certain tension generally prevailed and younger children did not follow directions. After the third lesson the children were in general very active, working collaboratively in the groups and producing very good results.

Some of the teachers (two in Part 1 and two in Part 2) additionally expressed their personal appraisal of the younger children's degree of collaboration in percentages for each month from the beginning of the activities. In the group meetings, the teachers expressed the thought that plotting these values might give us an idea of how the children's collaboration evolved over the period of group work in science activities. When these values were plotted they produced the graphs presented in Figures 10–13.

It is worth mentioning here that almost all the teachers, in both parts of the study, mentioned the children's eager interest in working with the science activities. Specifically, some of the teachers wrote that the *children marveled at the science activities and were excited about working together on them.* A representative photograph of a small group at work is shown in Figure 14.

Discussion and conclusions

The graphs of the performance of the younger children in each class in relation to the number of older children in their groups indicate that, in both parts of the study, there is a linear relationship between the maximum performance of the younger children and the number of older children in the group. The difference between the younger children's performance in classes where the groups were composed of both pre-kindergarteners and kindergarteners compared to those in the class where the groups were composed only of pre-kindergarteners can also be seen.

The high value of the coefficient R in the graphs indicates a good linear correlation between: (a) the variables 'younger children's performance' and 'number of older children in a group' and (b) the variables 'time in which the younger children in each class reached

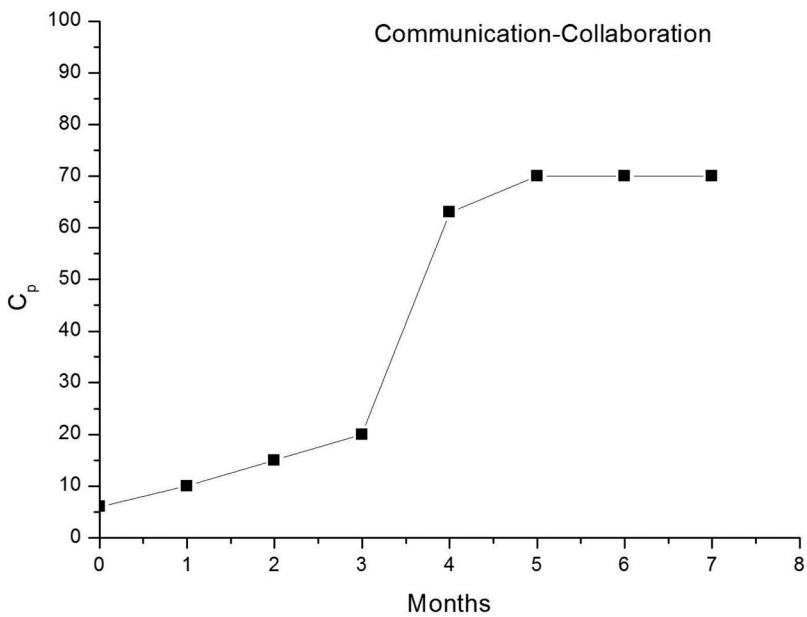

Figure 10. Degree of collaboration (C_p) for each month in a class with group composition of three pre-kindergarteners and two kindergarteners.

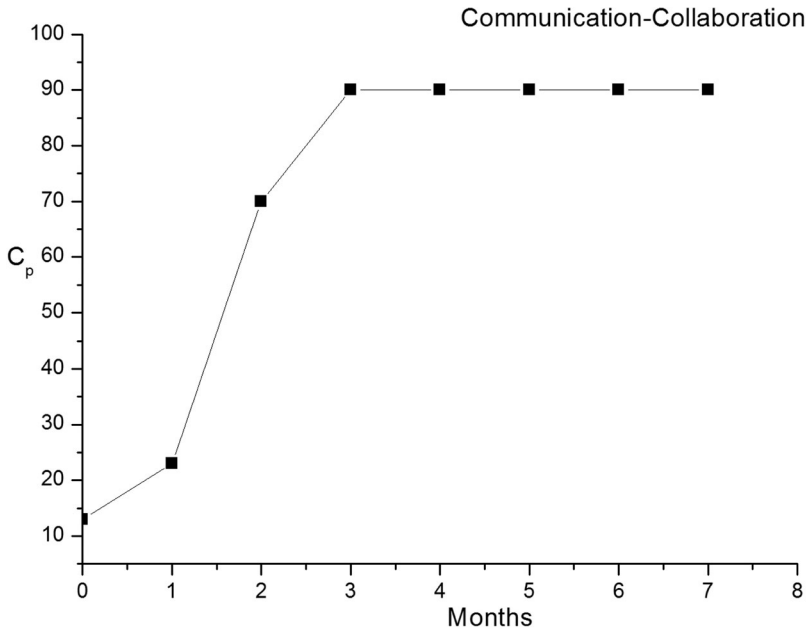

Figure 11. Degree of collaboration (C_p) for each month in a class with group composition of two pre-kindergarteners and three kindergarteners.

their maximum performance' and 'number of older children participating in the group' in each class. Plainly, the larger the number of older children in a group, the higher the younger children's performance in the science activities. Also the larger the number of older children in a group, the faster the younger ones reached their maximum performance.

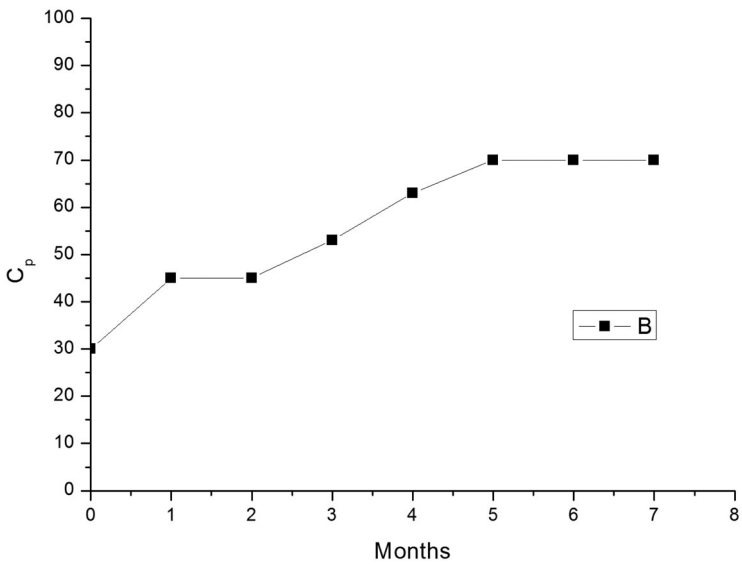

Figure 12. Degree of collaboration (C_p) for each month in a class with group composition of four pre-kindergarteners and one kindergartener.

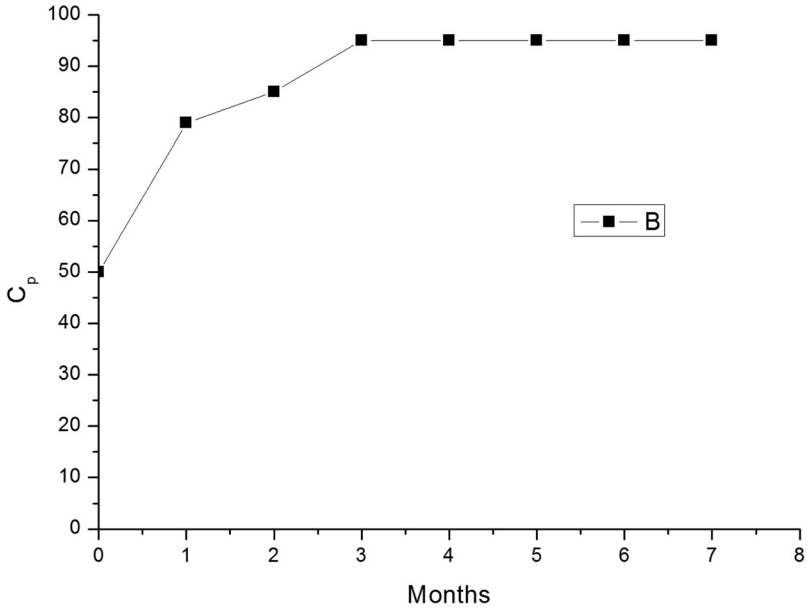

Figure 13. Degree of collaboration (C_p) for each month in a class with group composition of one pre-kindergartener and four kindergarteners.

Figure 14. Studying the 'conservation of mass'. Work in a group comprising two kindergarteners and three pre-kindergarteners.

Based on the linear relationship between the maximum performance of the younger children and the number of older children participating in the groups of each class, the expected performance of the younger children in a class can be predicted depending on the age composition of the small groups in this class.

It is interesting to note that in the second part of the study, as shown by the graphs, the performance E_p of the younger pre-primary children starts from a higher level than in the first part. When the issue was discussed in the group, the teachers gave various interpretations, based on their long classroom experience: as time passes, the children are exposed to more stimuli, interaction with sources like TV science programs, science books for very young children and the Internet gives them greater background knowledge. Also more and more children now attend daycare centers which provide an organized environment that helps them develop knowledge and solves adjustment problems before they enter kindergarten. Accumulation of knowledge and experience was also considered the explanation for why the primary children's performance started at a higher level than that of the pre-primary ones.

The graphs in Figures 10–13 provide some interesting side findings relating to the evolution of the degree of the younger children's collaboration with the older ones. The younger children's degree of collaboration seems to be related to the number of older children participating in the groups. This finding comes as corroboration of the teachers' recorded observations (described earlier in this work) about the evolution of the younger children's collaboration over the period of implementation of the science activities. However, as this particular finding comes only from the teachers' personal appraisal, systematic further research is needed to verify it. Also, the reported finding of the teachers in the first part of the study, that is, that as communication between the younger and older children increased the older ones began to instruct, advise and assign tasks to the younger ones, comes as an independent justification of what the research on social benefits reported by Katz (1995) shows, that is, that younger children assign instructional roles to older ones while older children assign to younger ones the need for help and instruction. It also comes as an independent justification of what Goularte (1995) maintains, that is, that older students can also provide direct instruction to younger ones. Additionally, the children's motivation and eager interest in working collaboratively with science activities, which was pointed out by the teachers in both parts of our study, are in line with what is reported by Krajcik et al. (2000): that in the context of inquiry-based pedagogy, teachers expressed satisfaction in seeing collaborating students motivated to learn. As was presented in the 'Design' section, the approach used in the science activities of our study was that of inquiry.

The outcomes of the present study show that in mixed-age small-group-learning in science the age composition of the groups can significantly affect cognitive achievement and preferentially determine the time in which this factor reaches its maximum value. The results can be interpreted on the basis of the findings of other studies reported earlier (Allen & Feldman, 1976; Peifer, 1971; Roberts, 1980; Thelen & Kirkland, 1976), which have shown that younger children learn from older ones, who constitute effective models for them, and also on the basis of studies (e.g. Gillies, 2003; Katz, 1995; Vygotsky, 1978) which maintain that in social interaction in small mixed-age groups, where students help, share and support each other's learning, younger children are more capable of completing tasks and contributing to far more complex activities than they could if they were by themselves. As Katz (1995, p. 30) specifically notes 'Once the older ones set up the activity, the younger ones can participate, even if they could not have initiated it.' Furthermore the context of inquiry provides rich opportunities for interaction during collaboration between the members of the groups (e.g. Hassard & Dias, 2009; Krajcik et al.,

2000). As Krajcik et al. (2000) suggest, collaboration and interaction during inquiry help students construct knowledge and introduce them to disciplinary language and ways of knowledge acquisition. In our study, as the children's collaboration in the groups evolved, interactions were promoted during which they shared ideas, instructed and listened to the others. Within this context the younger children in the mixed-age groups had the opportunity, by interacting with the older ones, to gain the benefits described earlier in our study (Katz, 1995; Vygotsky, 1978). The present study not only provides qualitative verification of these interpretations but also quantifies the role of the age composition of the small science-learning groups within a class.

Implications and further research

The present work has implications for planning and organizing learning in mixed-age settings.

Based on the findings, the selective composition of groups with a larger number of older children who have more advanced cognitive and communication skills in science can be used to facilitate both younger children's learning and their social interactions (Furman et al., 1979).

While findings should be interpreted within the limitations of a small-scale exploration study carried out in a single country, they may be used to guide research and interpretations of the effects of mixed-age grouping in science activities in other countries as well: for example, which age groupings in science activities might work best in which settings? The present study also raises other issues for further research: One interesting question that would be worth investigating is: What happens when a child in a mixed-age group is older but cognitively less abled than a younger child? Also, it is often claimed that teaching someone something improves learning for the one who does the teaching. It would, therefore, be interesting to investigate what might be the impact on the science learning of the older children participating in the mixed-age groups. Lodish (1993) notes that when older children 'teach' new skills to younger classmates they strengthen their own understanding of these skills.

Note

1. Correlation coefficient R is a measure of the strength and direction of the linear relationship between two variables X and Y, giving a value between +1 and −1 inclusive, where 1 is total positive correlation, 0 is no correlation and −1 is total negative correlation.

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Disclosure statement

No potential conflict of interest was reported by the authors.

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References

Allen, V. L., & Feldman, R. S. (1976). Studies on the role of tutor. In V. L. Allen (Ed.), *Children as tutors*. New York, NY: Academic Press.

Blumenfeld, P. C., Marx, R. W., Soloway, E., & Krajcik, J. (1996). Learning with peers: From small group cooperation to collaborative communities. *Educational Researcher*, *25*(8), 37–39.

European Commission (2007). *Science Education now: A renewed pedagogy for the future of Europe*. Luxemburg: Directorate-General for Research Science, Economy and Society, Publications of the European Communities.

Furman, W., Rahe, D., & Hartup, W. (1979). Rehabilitation of socially withdrawn preschool children through mixed-age and same-age socialization. *Child Development*, *50*(4), 915–922.

Gillies, R. M. (2003). Structuring cooperative group work in classrooms. *International Journal of Educational Research*, *39*, 35–49.

Goularte, R. (1995). *Multi-age classrooms*. Washington, DC: NEA Teacher-to-Teacher Books. National Education Association.

Hassard, J., & Dias, M. (2009). *The art of teaching science, inquiry and innovation in middle school and high school* (2nd ed.). New York, NY: Routledge.

Huber, G., & Huber, A. (2007). Structuring group interaction to promote thinking and learning during small group learning in high school settings. *Computer Supported Collaborative Learning*, *8*, 111–131.

Kallery, M. (2011). Astronomical concepts and events awareness for young children. *International Journal of Science Education*, *33*(3), 341–369.

Kallery, M. (2015). Science in early years' education: Introducing floating and sinking as a property of matter. *International Journal of Early Years Education*, *23*(1), 31–53.

Kallery, M. (2016). A 'Collaborative Partnership' Perspective on the Development of Activities for Professionally Upgrading Early-Years-Teachers in Science. Proceedings of the ESERA 2015 Conference: http://www.esera.org/publications/esera-conference-proceedings/science-education-research-esera-2015.

Katz, L. G. (1995). The benefits of mixed-age grouping. *ERIC Digest*. ED382411. Eugene: ERIC Clearinghouse on Educational Management, May. Retrieved from http://www.ed.gov/databases/ERIC_Digests/ed382411.html

Krajcik, J., Blumenfeld, P., Marx, R., & Soloway, E. (2000). Instructional, curricular, and technological supports for inquiry in science classrooms. In J. Minstrell & E. Van Zee (Eds.), *Inquiring into inquiry learning and teaching in science* (pp. 283–315). Washington, DC: AAAS.

Lodish, R. (1993). The Pros and Cons of mixed-age grouping. In R. Fogarty (Ed.), *The multiage classroom: A collection* (pp. 26–34). Palatine: IRI/Skylight Publishing.

Lou, Y., Abrami, P., Spence, J., Poulsen, C., Chambers, B., & d'Apollonia, S. (1996). Within-class grouping: A meta-analysis. *Review of Educational Research*, *66*, 423–458.

Merrick, S. (1996). *How to manage your multi-age classroom (K-2).* Huntington Beach: Teacher Created Materials.

Nastasi, B. K., & Clements, D. H. (1991). Research on cooperative learning: implications for practice. *School Psychology Review*, *20*(1), 110–131.

Peifer, M. R. (1971). *The effects of varying age-grade status of models on the imitative behavior of six-year-old boys* (Unpublished doctoral dissertation). University of Delaware.
Roberts, M. C. (1980). On being imitated: Effects of levels of imitation and imitator competence. *Social Psychology Quarterly*, *43*(2), 233–240.
Slavin, R. E. (1983). *Cooperative learning*. New York: Longman.
Thelen, M. H., & Kirkland, K. D. (1976). On status and being imitated: Effects on reciprocal imitation and attraction. *Journal of Personality and Social Psychology*, *33*, 691–697.
Vygotsky, L. (1978). *Mind in society: The development of higher psychological processes*. Cambridge, MA: Harvard University Press.
Wagner, L. (1982). *Peer teaching: Historical perspectives*. West Point, CT: Greenwood Press.
Webb, N. (1989). Peer interaction, problem-solving, and cognition: Multidisciplinary perspectives. *International Journal of Educational Research*, *13*, 1–119.
Webb, N., & Farivar, S. (1994). Promoting helping behavior in cooperative small groups in middle school mathematics. *American Educational Research Journal*, *31*, 369–395.

Appendix

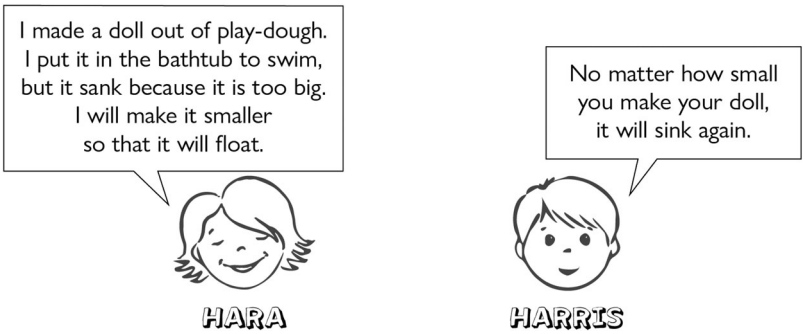
Sample of test items

Outer space

Identification, shape and movement of celestial bodies:
Task:
The child is given play-dough of two different colors, yellow and blue, and asked:
(1) to construct 'the sun' and 'the earth'; (2) to identify the celestial bodies, that is, to show which represents the sun and which the earth; and (3) to first explain orally and then show which of the two bodies is the one that moves [the sun was considered stationary in the design of the study] and next to first describe and then show, by moving the corresponding model, how this particular body moves [this makes it possible to diagnose whether what was described orally has been understood to a degree that can also be demonstrated].

Physics

Properties of matter(float and sink): Evaluating children's ability to dissociate floating/sinking from the object's size recognizing the material as the factor determining whether a body will float or sink in water.
Task:



The teacher presented the cartoons and read their arguments in a tone of voice resembling that of a real argument. Children were invited to judge each cartoon character's argument, express their own opinion and justify their view.
Teacher: What do you think? [Teacher waits for answer]. Can you explain why?