

# RESEARCH BOXES AND SCIENCE PROCESS SKILLS

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**Abstract** To develop basic science process skills, a preschool child requires science experiences of sufficient quality and frequency at both home and the kindergarten. The science education first formally offered to such a child significantly improves the development of science process skills like observing, classifying, categorising, comparing, counting, arranging, experimenting, predicting, inferring, formulating assumptions, communicating and researching. The above-mentioned science processes were included in designed picture task cards for 30 research boxes that were prepared to support learning in the natural sciences classes. They were used in kindergartens by 185 children aged mainly 4 to 6. We found that the children were successful in most tasks (at least 82 % of them) and that the majority of the children worked independently on simpler science processes. Although the task-card instructions exclusively contained pictures and symbols, this method of independently conducting activities still demands much from children if a child is encountering it for the first time. Given the children's motivation and performance, we recommend teachers to prepare more research boxes with topical science contents and accompany them with picture task cards in order to ensure the development of children's science process skills and independence.

**Keywords:**

science process skills, research box, picture task cards, preschool children, child's independence.

## Introduction

The development of pre-school children requires a comprehensive approach, as they should develop and master a range of psychomotor, emotional, social and cognitive skills from a variety of areas and contexts. In addition to the development of language, mathematics and art, learning by nature includes the natural and material world. Since learning at this age cannot be based on self-education and chance, there are many good reasons for involving children in organized forms of education. Given the complexity of the social, material and natural world of children in some countries, kindergarten curricula also include elements of technology and nature (Barenthien et al., 2019; Kurikulum za vrtce, 1999), where it is desired that a pre-school child should acquire considerable experience in a natural environment. Since the natural environment is often not accessible to children in a suitable form, it is useful to offer children certain materials that they can experience through free exploration, manipulation and experimentation. However, free play is often too restricted and rarely leads a child on its way to cognitive development. A child must be confronted with challenges in order to explore the offered material successfully and independently. Learning by exploring can become a way for a child to explore nature and the world around it (Krnjel, 2001).

Process skills (observing, inferring, classifying, measuring, predicting and communicating) are the fundamental basis of science teaching and learning because they guide scientific inquiries for children. The earlier children have experience with process skills, the better prepared they are for learning science. (Farland-Smith, 2015)

According to Farland-Smith (2015) and Skribe Dimec et al. (2007) the descriptions of *science processes skills* that was used in this research are the following:

*Observing* -the most essential skill for young children. Children experience the world around them with their senses. Observations can be made by seeing, hearing, smelling, touching and even tasting.

*Inferring* -a logical thought process that explains the relationships between reason or cause and effect. Children learn to carefully find the relationship between proof and explanation.

*Classifying* -the inevitable process of organising objects into groups based on observable characteristics. A visible classification system based on observations is an appropriate skill for pre-school children. If the groups are already set, then the process skills are called categorization.

*Comparing* -young children examine or look for the differences between two or more things, usually by observable characteristics and in a variety of ways appropriate to their stage of development. Descriptions of differences range from obvious differences to details.

*Arranging* -the process of organising objects into different orders. Children usually recognise the given order or create their own at an early age.

*Counting* -children say numbers for different subjects one after the other. It is mainly related to measuring.

*Measuring* -is process of using various measuring tools. Measurements for young learners can be carried out with comparisons between two objects and also with simple, non-standard measuring instruments.

*Predicting* -small children anticipate what will happen in a certain situation based on their experiences. They learn most when what they think will not happen as a result of scientific investigation. Predicting usually involves the ability to *make assumptions*.

*Experimenting* -a way of discovering, through questions or practical activities. Children use some simple gadgets to experiment with, such as magnets, cups, spoons, and some kitchen supplies.

*Researching* -in the context of young children this is mainly done by inquiring the topic, especially to get new information or to reach a new understanding. This includes simple experiments allowing the child more independency.

*Communicating* -it is important to give a new understanding in different ways, for example by writing words or a sentence, by drawing pictures, by making drawings and diagrams, and by talking about it.

To develop basic science process skills, a preschool child requires natural science experiences of sufficient quality and frequency both at home and in the kindergarten (Gropen et al., 2017; Piasta et al., 2015). The science education first formally offered to such a child significantly improves their development of science process skills and critical thinking, fills them with curiosity, open-mindedness, perseverance and scepticism that lead to progress in the skills of formulating hypotheses and the ability to identify problems. Moreover, it strengthens children's feeling that the world surrounding them is worth exploring, thereby creating a positive attitude to natural science (Kuru & Akman, 2017; Murphy & Smith, 2012). Despite scientific findings in support of the above, preschool teachers are still frequently deciding not to include science activities in kindergartens (Barenthien et al., 2019).

In recent times, as summarised by Jirout and Zimmerman (2015), one can find tendencies in early science education (for children aged 8 and below) that have altered the doctrines that not long ago, according to Piaget's theory of cognitive development, strictly stated that the learning of science process skills should be postponed until adolescence. Science education for small children often focuses on simple natural science processes like observation, description, comparison and discovery. Pre-schoolers are capable of understanding simple experiments aimed at testing hypotheses, recognising a control experiment, explaining simple observed patterns in research and using the results in further decisions or for making generalisations or predictions regarding future examples. A comparative study of research conducted over several years (Jirout & Zimmerman, 2015) reveals that pre-schoolers develop many simple scientific processes or demonstrate early signs of such skills. Nevertheless, many possibilities for development exist, underpinning the need for more research about the introduction of science process skills in kindergartens.

An important requirement of education is the development of a supportive environment that promotes lifelong learning. Early childhood education is a critical time in which experiences are made that enable and encourage children's willingness to engage in lifelong learning (Katz, 2010, as cited in Campbell et al., 2018). STEM at the early childhood level, if properly addressed, could provide educators opportunities to engage young children in activities that make use of their interests, experiences and prior knowledge (Campbell et al., 2018).

On the other hand, research also shows that the time currently spent in STEM early childhood is probably not sufficient to achieve positive educational outcomes (Saçkes et al., 2011)

Learning by exploring can be one of successful STEM practices that can be made even more interesting for a child and can be transformed into an independent task if a learning tool is provided alongside, such as research boxes (Skribe Dimec et al., 2007). A typical research box includes materials from a particular theme, such as interesting everyday items like stones, straws, nuts and bolts, keys and locks. Teachers may use also items that have their "story" like plaster casts of footprints, elements that can be tested, like water solubility, items related to a particular subject, such as certain animal, like birds, natural materials such as foliage, forest fruits, moss and similar.

The exterior of the research box is custom made according to the theme of the material. Inside the box there is a content card showing the contents of the box (Figure 1). Inside the box, in addition to the material, there are several work cards to guide the child as he or she explores. Examples of working cards for different natural science procedures are shown in Figures 2-7.



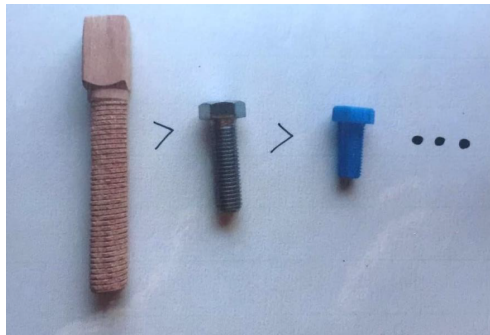
**Figure 1: Content card of 'Screws and Nuts' research box**  
(from archival material kept by Ungar and Šplajt, 2019)

The use of research boxes in a way sees children ‘asking nature’ because the task cards feature productive questions that are designed to encourage children to find answers from the material provided and not from books, computers or preschool teachers. Research boxes help children develop a range of science process skills like observing, classifying, measuring, experimenting as well as planning and conducting simple research. Using research boxes boosts children’s creativity since an answer to a question can be found in different ways during the research. To ensure children can be successful while independently exploring the research box materials, they must be able to understand the instructions. As pre-schoolers cannot yet read, the instructions should include pictures and symbols or feature realistic photographs of selected objects. This research aimed to establish how successful and independent preschool children are while working with these research boxes.

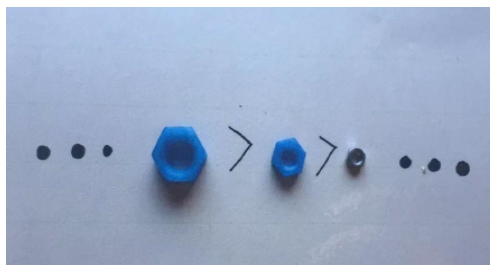
## **Methodology**

As part of practical sessions for the Didactic Approaches for Natural Environment Teaching subject for preschool education, students prepared (under supervision of the author of this paper) 30 different research boxes containing different materials and picture task cards; these were to guide children in their independent research, making them rely on different science process skills like observing, comparing, counting, classifying, categorising, arranging, experimenting, communicating, inferring, predicting, formulating assumptions and researching. Making measurements was not included. The research boxes contained simple natural materials or materials taken from everyday life, as suggested by Skribe Dimec et al. (2007). The themes included research into materials (e.g. magnetic properties, size of items, spices, kitchen materials), objects (e.g. plastic bottle caps, filled plastic eggs, nuts and screws) and natural materials (e.g. bird feathers, seashells, tree leaves). To get a better idea of the appearance of the research boxes prepared for the kindergarten test, descriptions of two more boxes with titles ‘Bird Feathers’ and ‘Plastic Caps’ are given in the appendix.

The tasks required that children use different senses; apart from observing and touching, the tasks included smelling and listening. Tasting was not a component. As this study called for the children to perform their tasks as independently as possible, the instructions containing pictures and symbols were prepared, as shown in Figure 2.



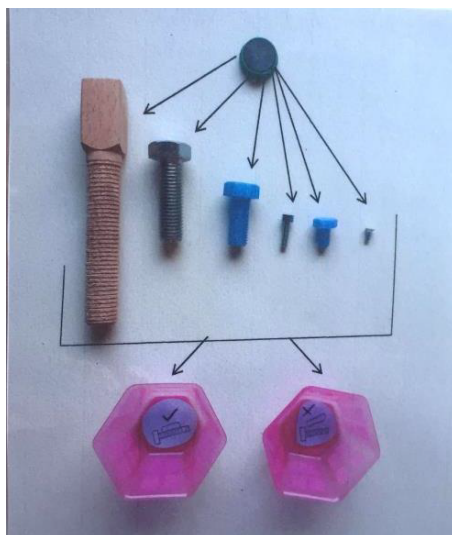
**Figure 2:** Example of a task card from the ‘Screws and Nuts’ research box -arranging screws  
(from archival material kept by Ungar and Šplajt, 2019)



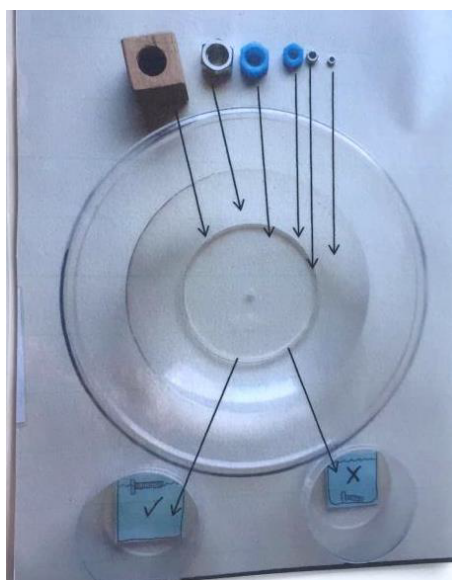
**Figure 3:** Example of a task card from the ‘Screws and Nuts’ research box -arranging nuts  
(from archival material kept by Ungar and Šplajt, 2019)



**Figure 4:** Example of a task card from the ‘Screws and Nuts’ research box -inferring  
(from archival material kept by Ungar and Šplajt, 2019)

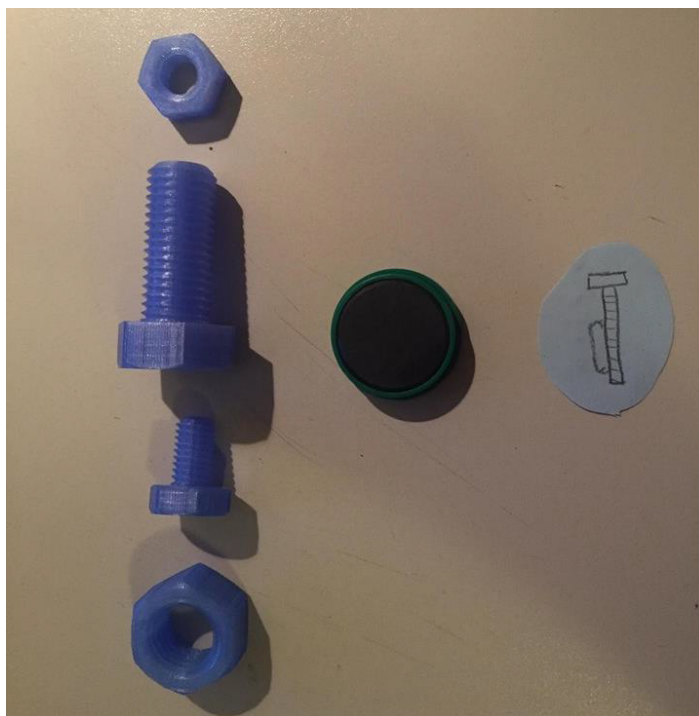


**Figure 5: Example of a task card from the ‘Screws and Nuts’ research box -experimenting with a magnet and categorising objects into magnetic and non-magnetic**  
(from archival material kept by Ungar and Šplajt, 2019)



**Figure 6: Example of a task card from the ‘Screws and Nuts’ research box -experimenting with water and categorising objects into those that float and those that sink**  
(from archival material kept by Ungar and Šplajt, 2019)





**Figure 7: Example of a task card from the ‘Screws and Nuts’ research box -researching: Are all plastic nuts and screws magnetic?**

(from archival material kept by Ungar and Šplajt, 2019)

The research sample consisted of 185 pre-schoolers from different kindergartens across Slovenia, where 160 children were aged from 4 to 6, and the rest were younger. The sample included 94 girls and 91 boys. A selected child was individually observed in their independent work on a research box, lasting up to 20 minutes. Data were gathered from April to June 2019.

The following research questions were formulated:

- Do the children understand the picture-based instructions?
- How independent are the children while working on a research box?
- How successful are the children in carrying out different science processes?

The results were recorded using an observation protocol where we noted down information on a child's age and gender, the science process featured on the task card, and the child's performance. While monitoring the performance, it was considered whether the child was independent and/or needed non-verbal/verbal assistance. Giving direct instructions was avoided as we wanted the child to first think about what the picture-based instruction could mean when confronted by the material found in the research box. Detailed general observations about the child's individual work with the research box were made.

The results were categorised and merged in a table where they were processed with Excel, using basic descriptive statistics. The descriptive results were evaluated in terms of their contents and then compared.

### **Research Results**

After testing and using the prepared research boxes, it was established that not all boxes contained task cards with all science processes. Most boxes, but not all of them, contained at least one task card related to observation, as 163 children performed tasks including observation (Table 1), representing 88 % of all the children in the research. Besides observation, the second and third most frequently used science processes applied to the research boxes were categorising (128 children) and classifying (127 children). More demanding science processes were found on a smaller number of task cards, with the least frequently used processes including communicating (6 children), formulating assumptions (16 children) and researching (38 children). Science processes that were regularly used included comparing, arranging, experimenting, predicting, inferring and counting, as Table 1 shows.

**Table 1: Results of the analysis of task-card use from the 30 research boxes along with the performance and independence of 185 children together (not all children participated in all science processes)**

Science process	no. of involved children	no. of successful children	% of success	no. of unsuccessful children	% of unsuccessful children	no. of independent children	% of independent children
observing	163	145	89	18	11	56	34
categorising	128	117	91	11	9	43	34
classifying	127	111	87	16	13	44	35
comparing	116	106	91	10	9	43	37
arranging	86	76	88	10	12	40	47
experimenting	84	74	88	10	12	21	25
predicting	68	61	90	7	10	27	40
inferring	55	52	95	3	5	14	25
counting	46	42	91	4	9	16	35
researching	38	31	82	7	18	7	18
formulating assumptions	16	14	87	2	13	6	38
communicating	6	6	100	0	0	3	50

The shares of successful children in Table 1 show that at least 82 % of children involved in a particular science process were successful in the implemented science processes. All children (albeit, only 6) tasked with communication were successful. As many as 95 % of the children were successful in inferring. The biggest share of unsuccessful children (only 18 %) was recorded in relation to the science processes of researching, followed by formulating assumptions (13 %) and classifying (13 %).

The results of this observation of a child's independence (last two columns in Table 1), namely the child did not need any non-verbal/verbal assistance but still successfully did the science process on the task card, show the children were most independent in communicating (50 % of all children completing this process), arranging (47 %) and predicting (40 %), followed by formulating assumptions, comparing, counting, classifying and categorising. Children were the least independent in researching (18 %) as well as in experimenting and inferring (both 25 %).

Regarding the children's understanding of the picture-based instructions on the task cards, it was established, based on observation notes, that children found it difficult to understand certain symbols used like a question mark (?), the less-than and greater-than signs (<, >) and the standard sign for continuation of the sequence (...). Some children had difficulty understanding the instructions for 'observing' or 'taking a look', where an eye was used as a symbol. It was established that some children still have problems recognising the objects in the photographs, as a photograph only shows a two-dimensional view of a selected object. Observation notes revealed the children were highly motivated to participate and showed perseverance in performing the tasks and exploring the prepared materials in the research boxes.

### **Discussion and Conclusion**

The use of simpler science processes, such as observing, comparing, classifying and categorising, gives foundations for pre-schoolers upon which they can build their understanding of the world surrounding them, which is why these processes are included in different planned activities, as established by Jirout and Zimmerman (2015), in many research studies. The fact that most of the task cards in the research boxes (used as a learning tool) featured the above-mentioned simpler science processes confirms the boxes were prepared appropriately. We also established that the children were generally very successful in doing all of the tasks. One trend that is noticeable is that the success rate drops from simpler to more demanding science processes, as researching and formulating assumptions are considered to be less successful processes. Although a smaller share of children was involved in the more demanding science processes, it may be concluded from the results that more demanding science processes, provided they are appropriately prepared, can be included in preschool education as well, and thus give an excellent basis for the development of real scientific research in adulthood.

Since the share of children who performed their tasks completely independently was smaller than of those who successfully implemented the tasks, we can conclude that many children failed to understand the picture-based instructions on the task cards and required non-verbal/verbal assistance. Observation notes reveal a trend of older children being more independent, which is associated with their better understanding of symbolic notations that are learned while completing various tasks in children's magazines or on a computer or smart phone. However, the mentioned

assumptions call for more research attention to confirm such correlations. The science processes of researching and experimenting as well as consequent inferring, in the performance of which the children in this research were the least independent, corroborate the findings of some studies (Barenthien et al., 2019; Gropen et al., 2017; Piasta et al., 2015), showing that children lack sufficient experience and opportunities to conduct experiments based on simple research questions and, as expected, become less independent.

The desire to see children work independently on a research box and its natural science contents and materials guided us in the design of the picture task cards featuring symbols. Certain agreed-upon symbols were used, such as a question mark, three dots to denote continuation of the sequence, the mathematical less-than and greater-than signs as well as some symbols arising from pictographs because of the fact that most pre-schoolers cannot read. Children only formally learn about symbols in later years of primary school. Nevertheless, the children still showed considerable misunderstanding of the prepared picture-based instructions. We assume that understanding of picture-based instructions would improve if a child could work on several research boxes containing similar instructions and symbols.

The carefully prepared research boxes with picture and symbol-based instructions are an excellent science tool for developing the science process skills of preschool children aged 4 to 6. The use of research boxes facilitates children's individualisation and differentiation as they become more successful and, when using the research boxes frequently, also more independent. While, as a rule, children are more successful and independent in developing simpler science process skills like observation, categorisation and classification, this study's research findings confirm it is reasonable to also include and develop more demanding science process skills such as experimenting, inferring and researching. By using research boxes in this extremely motivating activity, preschool children are able to build a foundation for themselves for the later development of actual research work methods in adulthood.

Preschool teachers are recommended to upgrade group, frontal and guided science activities in which children learn the basics of specific natural sciences, aids and processes, as well as offer them to children in an individual independent form, i.e. research boxes.

## Acknowledgement

Financial contributions from the project “NA-MA POTI - Operation partly financed by the European Union, European Social Fund” have made this research project possible.

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## Appendix 1

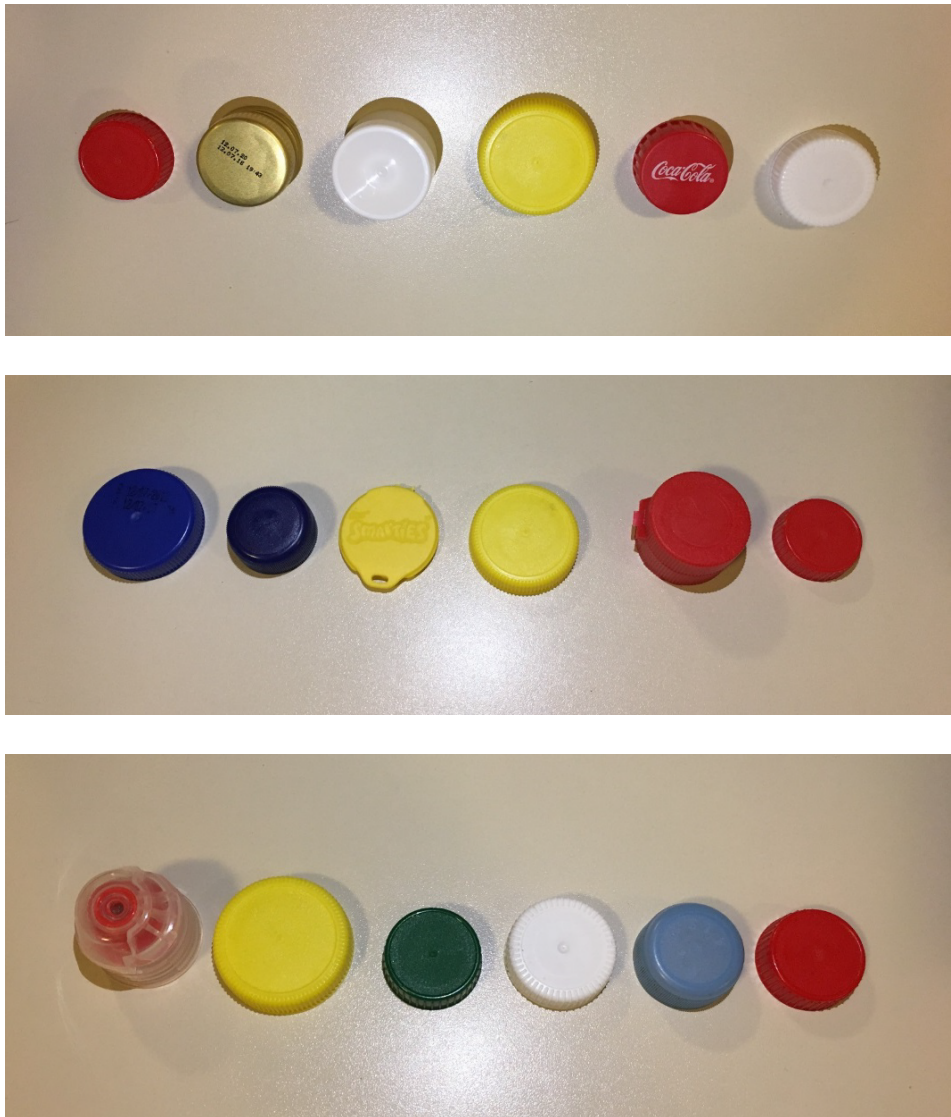
### Presentation of the research box 'Plastic Caps'



**Figure 8:** The exterior of the research box 'Plastic Caps'  
(from archival material kept by Bezjak and Pirnat, 2019)



**Figure 9:** Material included in the research box 'Plastic Caps' (caps, cut off bottle necks, ribbons, a box of semolina, blades) and task cards  
(from archival material kept by Bezjak and Pirnat, 2019)



**Figure 10: Example of a task card from the 'Plastic Caps' research box -arranging according to the pattern**

(from archival material kept by Bezjak and Pirnat, 2019)



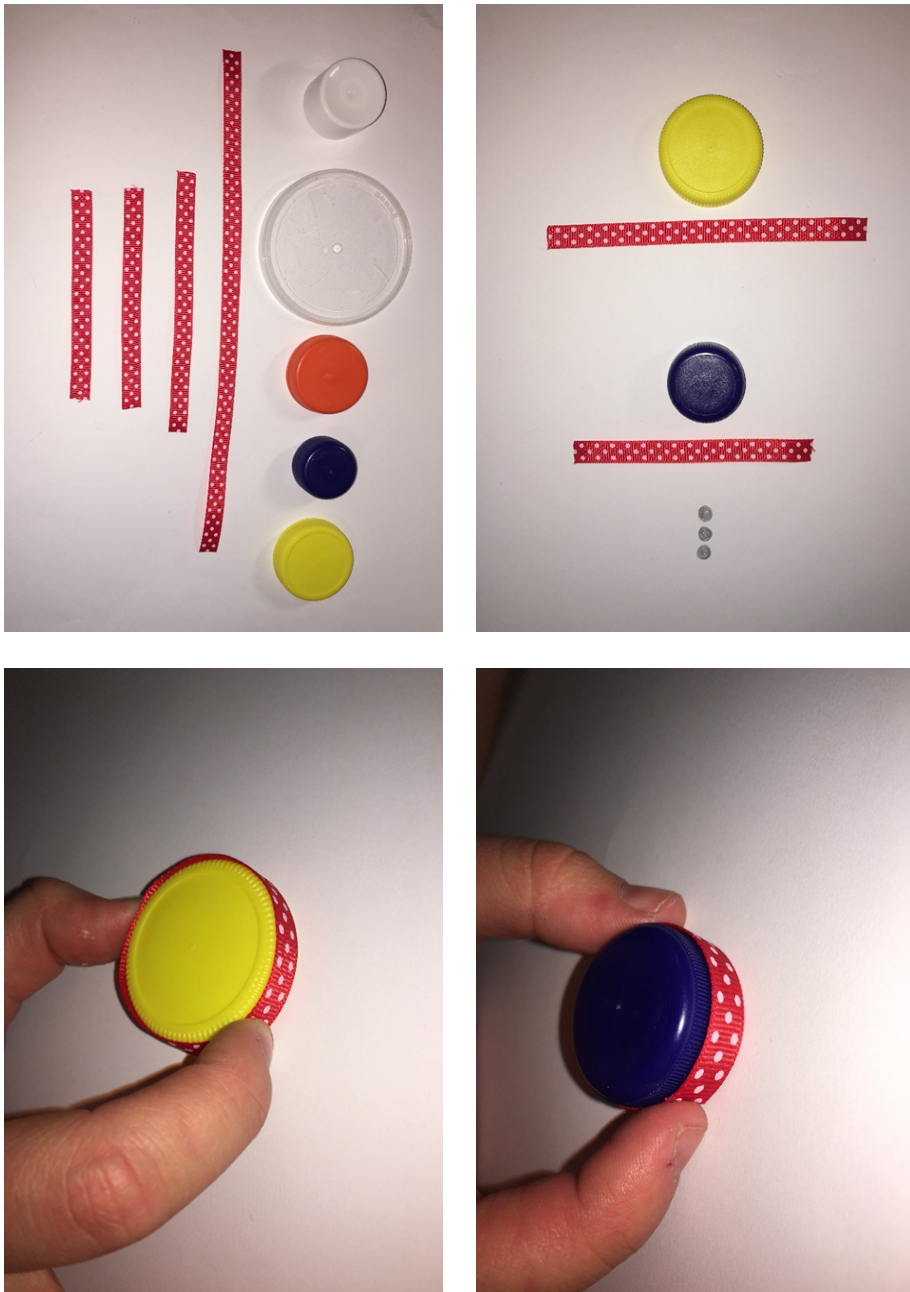


Figure 11: Example of a task card from the 'Plastic Caps' research box -measurement of the circumference of a cap (a multi-step instruction)  
(from archival material kept by Bezjak and Pirnat, 2019)

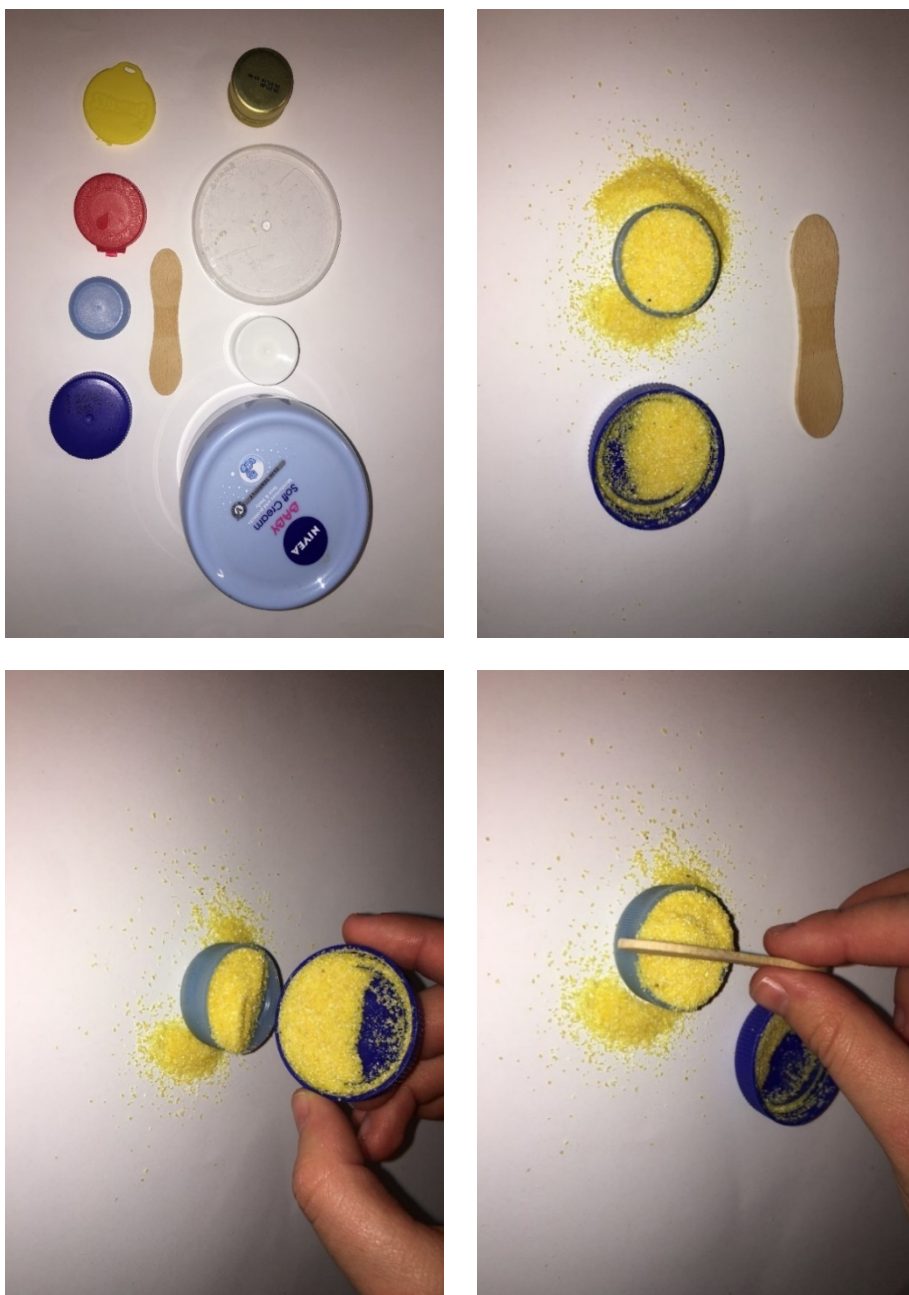
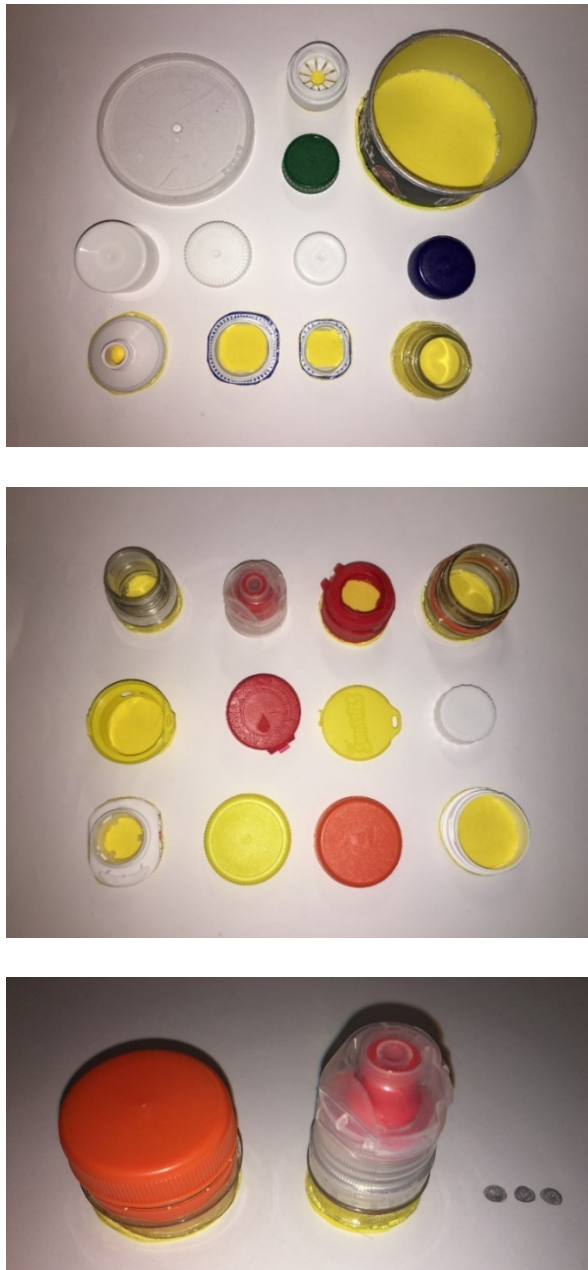


Figure 12: Example of a task card from the 'Plastic Caps' research box -experimenting and comparing the amount of semolina in caps (a multi-step instruction)  
(from archival material kept by Bezjak and Pirnat, 2019)



**Figure 13: Example of a task card from the 'Plastic Caps' research box -arranging and measuring with a non-standard tool, comparing (a multi-step instruction)**  
(from archival material kept by Bezjak and Pirnat, 2019)



**Figure 14: Example of a task card from the ‘Plastic Caps’ research box - experimenting and inferring caps and bottle necks (a multi-step instruction)**  
(from archival material kept by Bezjak and Pirnat, 2019)



**Figure 15: Examples of task cards from the 'Plastic Caps' research box from top to right sorting: classifying by colours, observing, inferring caps and bottle necks, experimenting rolling test, classifying by size, communicating**  
(from archival material kept by Aberšek and Lepej, 2019)

## Appendix 2

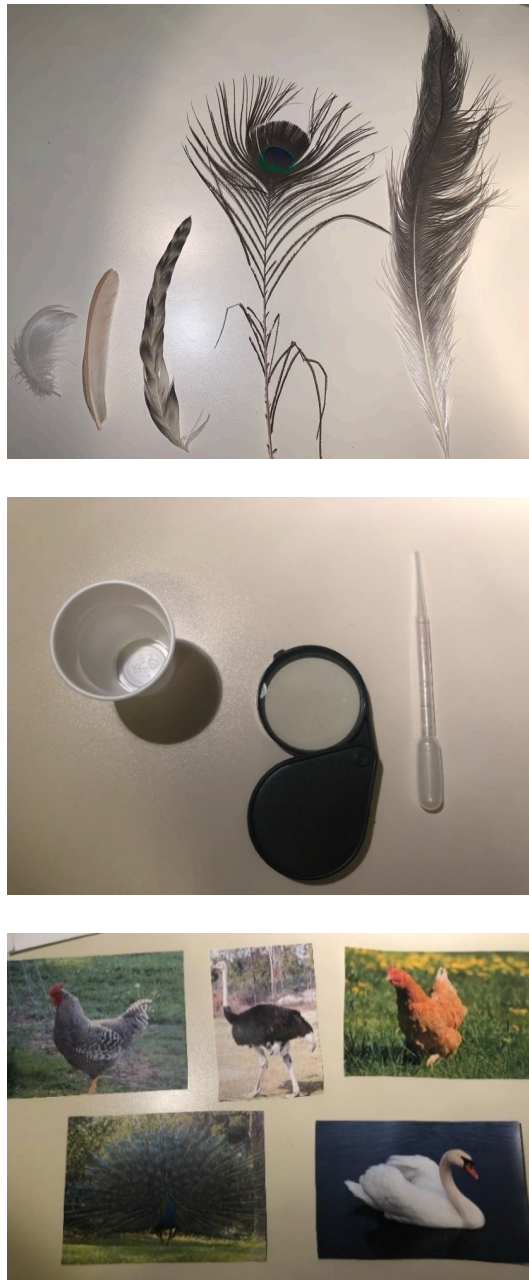
## Presentation of the research box 'Bird Feathers'



**Figure 16:** The exterior of the 'Bird Feathers' research box  
(from archival material kept by Smiljan, Radolič and Pelc, 2019)

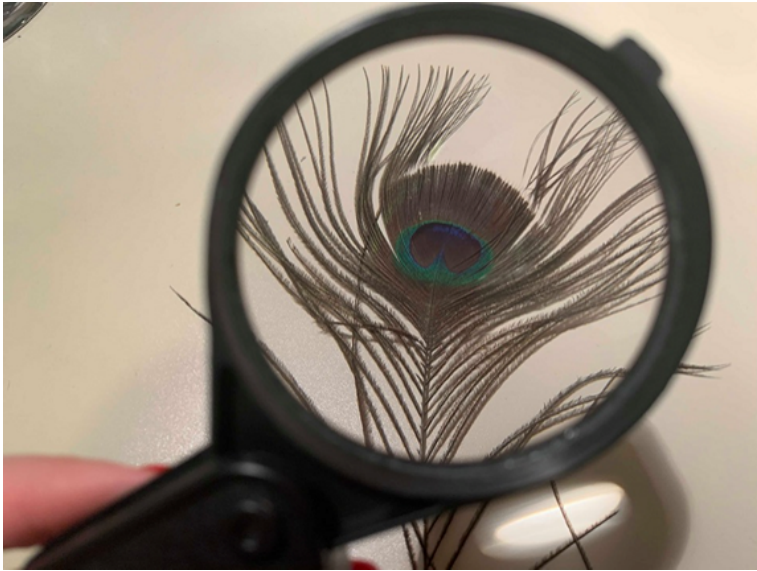


**Figure 17:** Material included in the research box 'Bird Feathers'  
(from archival material kept by Forjan and Kisilak, 2019)



**Figure 18: Content card of the 'Bird Feathers' research box (feathers, magnifier, water pot with dropper, bird photos)**

(from archival material kept by Forjan and Kisilak, 2019)



**Figure 19:** Example of a task card from the 'Bird Feathers' research box -observing the difference in branched structures using magnifier  
(from archival material kept by Forjan and Kisilak, 2019)



**Figure 20:** Example of a task card from the 'Bird Feathers' research box -arranging  
(from archival material kept by Forjan and Kisilak, 2019)





**Figure 21: Example of a task card from the 'Bird Feathers' research box -inferring which feather belongs to which bird**  
(from archival material kept by Forjan and Kisilak, 2019)



**Figure 22: Example of a task card from the 'Bird Feathers' research box -experimenting:  
What happens to the dripping water on the feather?**  
(from archival material kept by Forjan and Kisilak, 2019)



**Figure 23: Example of a task card from the 'Bird Feathers' research box -comparing two selected feathers and communicating**  
(from archival material kept by Forjan and Kisilak, 2019)