CHAPTER 2

Uses of Augmented Reality for Development of Natural Literacy in Pre-Primary Education

Kateřina Jančaříková and Eva Severini

Abstract

The chapter focuses on the educational potential of augmented reality for support of scientific literacy in pre-primary education. Development of scientific abstraction in preschool children (aged 3–7) is one of the goals of scientific pre-literacy (Jančaříková, 2015). The chapter presents the opportunities that augmented reality brings to development of scientific literacy. The authors give a brief overview of the area and of selected applications suitable for preschool children. They then focus on two of them, 4D animal and Quiver Vision, which were used in a research project involving two Czech and two Slovak kindergartens as well as 5 preschool children's parents. Improvement of the learning process and of teaching methods contributes to a child's complex development in the contemporary socio-cultural context. That is why the goal of the presented research was to identify the impact of the use of augmented reality on the development of children's scientific literacy as well as on the teachers' professional development. This action research project was conducted within the frame of science education context and included semi-structured interviews with teachers from a learning/play community of children involved in the research, and preschool children's parents, as well as direct and indirect observations of children while involved with augmented reality in educational activities. The research showed that many teachers were not familiar with the technology of augmented reality, and some teachers expressed worries about how to employ augmented reality with preschool-age children. Additionally, the teachers shared creative ideas on how these technologies can be included in the offered activities.

Keywords

augmented reality – natural literacy – pre-primary education – qualitative methodology – work with models

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1 Theory

1.1 *Introduction*

Information and communication technology and especially applications with augmented reality are of unprecedented potential and allow teachers to present very complex objects and processes in the classroom, which teachers increasingly make use of. But do pupils understand these models? What can be done to support understanding? How can misconceptions be minimalised? How can scientific abstraction in preschool children be developed in the right way to ensure pupils' and students' success in the years to come?

If we want to understand augmented reality well and use it in science education optimally, it must be perceived in a wider context. Development of science literacy is an indispensable part of general education. The special goals that activities with preschool children should target are defined as follows:

– Development of sensitivity to nature (environmental sensitivity) built on the relationship to specific animals, trees, plants and products of nature or to some landscape and natural environment and experiences in this environment;
– Development of vocabulary in the domain of nature and environment, of language skills that allow a child to describe their experience or observation or to understand their teacher, classmates, educational TV programmes, and of communicative competence including the courage to ask about things they do not know;
– Development of a system of basic knowledge about the realm of nature (e.g., that fish die if not in water, etc.) that is not necessarily verbalised;
– Acquisition of skills and routines enabling development and deepening of knowledge of nature, including inquisitiveness, interest, creativity, observation, bases for science experiment, use of simple tools of measurement, and mastering of work with models;
– Mastering of self-management and hygienic routines, i.e., those that enable risk-free scientific activity, for example, eating no berries in nature without an adult's consent, keeping shoes and garments dry (does not deliberately walk through puddles), washing hands without being told, etc.;
– Identification of children and pupils with scientific talent and their support (Jančaříková & Jančařík, 2016).

One of the objectives of science literacy is the ability to understand models (Jančaříková, 2015). This objective comes out of the conclusions of PISA (OECD, 2007), which defines work with models – in a broad sense of "model," including two-dimensional projections and images, computer simulations and others – as one of the problematic areas in science education.

1.2 *Models*

1.2.1 Definition of Models

Models are defined as provisional objects that enhance pupils' ideas and conceptions, specify abstract systems of concepts and support in pupils' connection of acquired knowledge to real life. Work with models is (among other) included in the Demonstration Method (Skalková, 1999). A model in natural sciences is an *object that represents a natural object or phenomenon*. Didactics of chemistry often use the term *representational structures* for models and *mental models* for students' understanding of models.

To understand what models, represent efficiently, a pupil requires a very specific understanding of the relationship between the model and the real object it is meant to represent.

It is very difficult to master this specific skill (Machková & Bílek, 2013). Different authors look at it from different points of view; the very naming of this skill is very difficult. Some authors refer to this skill as the *ability to understand visual language* (or better, "visual languages," because in various cultural contexts the same scheme can have very different meanings) and develop the *theory of visual languages* (Chang, Tauber, Yu, & Yu, 1989). Hortin speaks of *visual literacy*, defined as the ability to understand ("read") and use ("create") images and to think and learn in *terms of images* (Hortin, 1980). For example, when reading a map, understanding the symbolic relationship between a map and the real landscape as well as the symbolic function of signs is essential (Kosslyn, 1989). Slavík (2001) uses the term *isomorphism*. Skalková uses the term *abstraction*, which she specifies as the ability to create new images with the help of illustrative visual aids (Skalková, 2007). For this chapter, we decided to use the term *natural science abstraction*.

Whatever this specific ability is called by researchers, it is obvious pupils need specific skills in order to understand a complex model and to connect, in their minds, a model's properties to the properties of the real object they are learning about in the so-called "recoding" process.

1.2.2 Classification of Models

With respect to their purpose, models in natural sciences can be divided into two basic groups:

1. models of objects; and
2. models of relationships and processes including model solutions of problems (Jančaříková & Jančařík, 2016).

Both of these groups are often interconnected in school practice and it is not always possible to isolate one from the other. For example, a model of the solar system not only gives information on individual planets but also gives a lot of information about their relationships, possible positions, orbits, etc. On a higher level of abstraction, the model of an atom in not only its physical visualisation, but also a schematic indication of the relationships between the particles that make up an atom.

Models of objects can be divided into several basic categories, including:
– Visualisations;
– 3D models;
– Collections of products of nature; and
– Living (model) organisms.

Visualisations

Visualisations can be in colour or black-and-white, can be of different sizes and proportions, can require small to medium levels of abstraction. Visualisations include drawings, paintings, photographs as well as various types of projections – static projections (slides, products of nature placed on an over-head projector or PowerPoint presentations) and dynamic projections (videos and films, including animated films).

Laics often believe the best way to visualise a product of nature is a photograph, but this is a mistake. In contrast to a photograph, a scientific illustration enables the author to emphasise the features important for determination of the specific species or features and properties specific for different seasons (see Figure 2.1), and thus visualisation of the given species is more fitting.

The theory of illustration is quite advanced. Čáp and Mareš (2001) present a classification of visual materials according to their function as follows:
a. decorative – those that are not related to the text;
b. representative – those that provide an adequate visual image of the represented object;
c. organizing – those that require procedural knowledge (e.g., manuals, instructions, phased images, sketches, flowcharts, etc.); and
d. interpreting – those that help understand in areas that go beyond pupils' experience.

All authors warn of creation of misconceptions in case of a poorly selected illustration. That is why it seems appropriate not to plan lessons only with one type of visualisation but to make use of multiple types including three-dimensional models.

Three-dimensional models

Three-dimensional (3D) models are objects that visualise a selected natural-science entity. A teacher should present to children and pupils models made of different materials (wood, plastic, plush, etc.), of different colours and sizes. Figure 2.2 presents a selection of models used in natural science activities with

FIGURE 2.1 Visualisation, Department of Biology and Environmental Studies, Charles University, Faculty of Education

FIGURE 2.2 Selected aids used by the author for development of science literacy in primary home schoolers

preschool children. The photograph includes reduced models (the model of solar system, dinosaur and elephant), enlarged models (models of the lifecycle of a ladybird, ant, stag beetle and mosquito), and real-sized models (models of a bat or plant germination). (Figure 2.2 also includes an illustration of the process of hatching and growth of a duck, which is not a 3D model.)

Thanks to the development of technologies, we come more and more often across 3D interactive models that pupils can view on computer monitors, using a stereoscopic projection and augmented reality, (which will be the focus of this chapter).

Products of nature, including animal and plant collections and preparations
In a broader sense, a specific type of 3D models are products of nature. Preparations are either temporary or permanent. Preparations and other products of nature are those that are made within a lesson and disposed of after the lesson, for example, protozoans in an infusion of hay that can be observed alive with a microscope. Permanent preparations are for example animal mounts (see Figure 2.3) and their parts (skeleton, leg with claws etc.) but also items from herbariums and collections, for example, an entomological collection, a collection of shells and seashells (see Figure 2.4) or a collection of rocks and minerals. Preparations can also be microscopic. There are several companies in the Czech Republic that sell whole sets of preparations related to different areas to schools.

When preparing and studying a real natural object, pupils use more senses (e.g., touch, smell) and thus gain experience irreplaceable even by the most up-to-date technology.

This category also includes mounted animals, preparations and collections of beetles, butterflies and items from herbariums, although demonstration of a mounted animal borders on visualisation and work with a model.[1] Natural science collections are a particularity of science education. One of the needed competences of teachers of biology is thus taxonomy and preservation of products of nature. This is taught at Charles University, Faculty of Education also within the frame of in-service teacher training.

FIGURE 2.3 Mounted birds (Falco peregrinus, Circus aeruginosus, Pica pica) of Department of Biology and Environmental Studies, Charles University, Faculty of Education, stuffed under supervision of Jan Řezníček, Ph.D.

FIGURE 2.4 Natural science collection of Department of Biology and Environmental Studies, Charles University, Faculty of Education

Living organisms
When teaching biology, not only models but also living organisms are used, especially to meet the didactic principle of illustrativeness and for comparison with models. Observation of living organisms in their natural habitat helps pupils learn not only about the organism itself but also about its relationships and interactions with its environment. However, it would be wrong to think that introduction of living organisms is sufficient. The didactic goal of using living organisms is not only that pupils get introduced to the given organism but also secondarily work with a model and natural science abstraction.

Model organisms are used for direct observation. A *model organism* is such that is explored by pupils not only to study the organism itself but also to develop their ability to explore and to expand their knowledge of the diversity of living organisms.

A model organism is studied in great detail and children and pupils are expected to be able to generalize and transform knowledge and methods of studying and exploration to other organisms and objects.

It is striking that the selection of model organisms as such is methodologically underdeveloped at the level of pre-schoolers, as well as at primary and secondary levels. However, there are some model organisms that have been used at schools for hundreds of years, including earthworms and bees, which have been used in textbooks since the time of Austro-Hungarian Empire. Jančaříková (2015) describes the criteria for selection of model organisms and work with them in detail.

An unusual model organism was selected by Hanel and Hanelová (2014). These are the true bugs *Elasmucha grisea*, which are abundant on birches from May to July, are not protected by the law and show very interesting and easily observable parental behaviour. Observation of these beetles gives an opportunity for inquiry-based education.

Models of relationships and processes

As with models of objects, models of processes and relationships can be divided into several categories, which are:

- Static schemes;
- Dynamic schemes;
- Dynamic models;
- Interactive models; and
- Proper (model) observation.

Static schemes

A static scheme is the depiction of a relationship or process that a pupil must learn. Static schemes put high demands on the pupil's ability to abstract, for the pupil must make conjectures and recode the presented information into the structures in their minds. On the other hand, static schemes make it possible to describe and emphasise the main parts of a process and partly also the conditions under which these processes take place. The Internet offers a wide range of schemes describing processes and relationships (see, e.g., Figure 2.5).

Dynamic schemes

A dynamic scheme allows pupils to observe the course of some process. In computer created dynamic schemes, pupils can select which parts of the process they want to study and observe the schematic depiction of their progress. For example, the application *Body 4D*[2] allows pupils to study the human heart in Augmented Reality, which means they see its activity, hear its beating and can view it from different angles, magnify any of its parts and observe its activity at different stages.

Dynamic models

Dynamic models allow pupils to study and explore not only objects but especially processes. Preschool children prefer dynamic interactive models. An

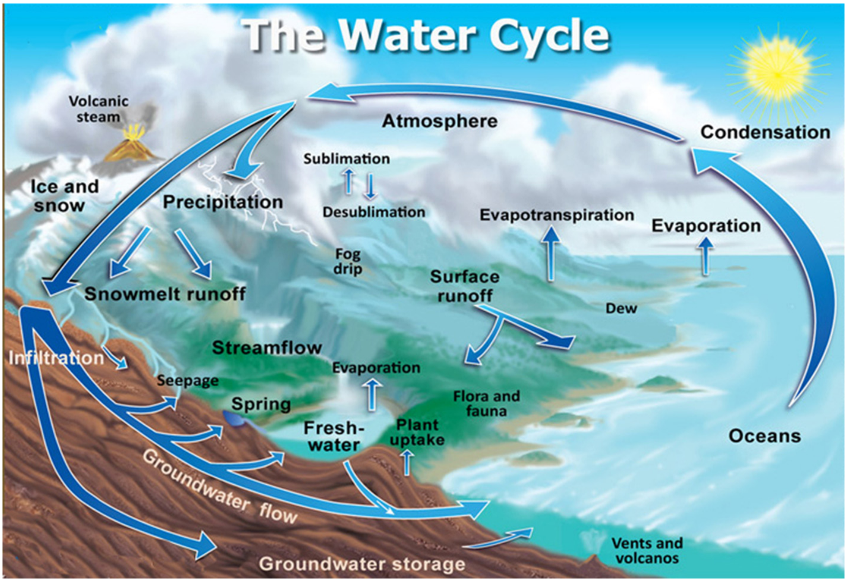

FIGURE 2.5 Scheme of the water cycle (by John Evans and Howard Periman, USGS, http://ga.water.usgs.gov/edu/watercycle.html, Public Domain, https://commons.wikimedia.org/w/index.php?curid=26818355)

FIGURE 2.6 The dynamic three-dimensional model of childbirth allows manipulation and thus demonstrates the process more fittingly. The model is in the collection of the Department of Biology and Environmental Studies, Charles University, Faculty of Education

example of such a model is a toy kangaroo with a baby that a preschool child (or other child) can put into and take out of the mother's pouch. Another example is the model of the birth of a baby shown in Figure 2.6.

Interactive models

Interactive models allow pupils not only to observe the course of some activity/process but also to influence it by changing various parameters. Interactive applications usually make use of mathematical models describing individual phenomena and their mutual relationships. One of the best-known examples is the simulation of sizes of populations of hares and foxes in nature, which is used when teaching ecology.[3]

1.2.3 A New Era of Models

Development in technologies brought a new era of models with new potential but also new demands on the user. Virtual environments and applications with augmented reality allow 21st century biologists to study models of objects they cannot touch (e.g., DNA double helix, cell, atom) and to simulate phenomena that cannot be observed with human eyes (e.g., mitosis). Thanks to virtual environments, environmental scientists are able to formulate better hypotheses about structure and functions which they verify using computer simulations. New technologies are no longer used only by researchers and in tertiary education, they have entered schools and also preschool education (Johnson et al., 1998).

However, grasping a model transferred into a virtual environment puts high demands on the user. Recoding the relationship between the real object and its model or simulation correctly requires developed abstract thinking. The more complex the model or the simulation, the more abstract thinking is needed to grasp it correctly.

PISA studies (OECD, 2007) show that many (Czech and Slovak) pupils struggle to grasp a model correctly.

In correspondence to the principle of small steps, scientific abstraction should be developed systematically. It cannot be acquired quickly. Pupils cannot be expected to understand a complex simulation in augmented reality without sufficient previous training to fully acquire the new subject matter.

1.2.4 Augmented Reality

The main sense of using augmented reality is to provide a real environment with digital information and images. Many applications augment reality with playful elements, but their education potential is negligible. With respect to science education, such fun elements are not beneficial and may be counterproductive, because they not support creation of the student's understanding of scientific concepts (Jančaříková, 2015).

However, the educational potential of some applications is immense. An example of how augmented reality can be used in science education is the application for Android, Star Walk 2 – Night Sky Guide, which allows users to identify stars and constellations in the night sky. If the user observes the sky using the camera of their tablet, they can see not only various celestial objects along with their names and other relevant interesting information. Star Walk Kids – Explore Space is adapted for children.

Several studies were conducted confirming the great potential of augmented reality for development of scientific imagination (e.g., Hamilton, 2011; Kaufmann, 2004).

Critical voices warn of related dangers, the most serious of which is cognitive overload (Carpenter, 2010).

A whole range of applications whose goal is to develop science literacy was developed for pre-primary children. Some of them are run using special cards, for example, AR Animal, an application for iPhone and Android. If the user focuses the camera on a special card, a 3D visualisation making simple movements appears. At the same time a voice recording with more information about the animal is played. Another example is Animal 4D+, an application for iPhone and Android. If the user focuses the camera on a special card, a 3D visualisation making simple movements appears. Some cards interact, for example, the card with a monkey and banana (the monkey tears the banana, peels it and eats it).

Other applications are run if the child colours a picture. For example, the application Quiver provides a wide range of pictures (volcanos, cells, etc.), which, if coloured by a child, are augmented by 3D models. If the child taps on the tablet display, the model behaves as a dynamic model, for example in the case of a volcano, lava starts rising, which is followed by an explosion. This process is accompanied by sound effects.

1.3 *Virtual Reality at the Preschool Level*

It is only logical to commence with intentional development of scientific abstraction as soon as possible, even as early as the pre-primary level. Developmental specifics of this group should not represent an obstacle. Piaget states that at the preoperational stage (2–4 years) children are already able to work with symbols and start to understand that simple visualisations, projections and models represent real things (Piaget, 1973).

Many engaged parents and educators have recently asked the following questions: "Is it meaningful to use tools of augmented reality for development of scientific abstraction in preschool children?"

Contero and his colleagues (2012) analysed the efficiency of the activity "Animals" in a group of preschool children (aged 4–5). Participants were split into two groups. The same programme was conducted with both groups but in one group the activity was supplemented by a presentation of animals in augmented reality. The results indicate that children in the augmented reality group achieved better results than children from the control group.

Han Jo, Hyun, and Hyo-Jeong (2015) describe how a group of Korean experts from various fields (preschool educators, preschool teachers, specialists in augmented reality and robotics) cooperated on the development of an educational activity with augmented reality for preschool children. Subsequently this activity was experimentally tested in a kindergarten. The results imply that applications with augmented reality can be useful in preschool education.

Cascales, Pérez-López and Contero studied the relationship of preschool children to applications offering augmented reality. Their study proves that parents are well aware of the benefits augmented reality can bring (Cascales, Pérez-López, & Contero, 2013).

However, a meta-study conducted in 2014 in Japan points at a high variability of efficiency of the use of applications with augmented reality. Its authors found 87 research reports focusing on the study of teaching supported with augmented reality (ARLE) in the digital library IEEE Xplore and other publications on educational technology. Efficiency of the use of augmented reality varied considerably. Some studies report negative impact, some average or moderate effects (Santos, Chen, Taketomi, Yamamoto, Miyazaki, & Kato, 2014). This is easy to explain. Similar to other didactical aids, applications with augmented reality are self-sustaining. If their impact on educational process is to be positive, they must be used in a systematic and thoughtful way. Dayang Rohaya and his colleagues (2012) show that communication, discussions, and telling stories are essential while working with applications with augmented reality. Or they use augmented reality to introduce stories in a more attractive form.

We tried to consider what aspects of work with augmented reality with preschool children can be made more efficient and came to the conclusion that augmented reality must be used in accordance with didactical principles of science education. As these principles are not generally known, we decided to present a brief survey of them in the following section.

1.4 *Didactical Principles for Use of Applications with Augmented Reality at the Preschool Level*

1.4.1 The Principle of Partial Educational Guidance (Process as the Goal)

This principle, first formulated probably by the first Swiss educator, philosopher and reformer Johann Heinrich Pestalozzi, points at the fact that apart from knowledge objectives, we must always bear in mind the partial objectives. In the context of science education these partial goals are namely:

- To develop vocabulary and speech,
- To master work methods including rules of safety and the ability to cooperate,

- To master the ability to work with various types of visualizations,
- To master the ability to work with models,
- To develop environmental sensitivity,
- To adapt appropriate behaviour patterns, including ethical patterns,
- To experience joy of discovery (Jančaříková, 2015).

All these partial goals must receive attention when using applications with augmented reality.

1.4.2 The Principle of Scientific Quality

The principle of scientific quality states that teachers should be using scientific reasoning, procedures and language when communicating with children during activities. Applications with augmented reality can help preschool children learn to differentiate between real and fictional. A teacher should make sure they select those applications with augmented reality from the wide offer that present reality with a high degree of accuracy and should avoid the use of those that distort reality inappropriately. It is equally important that augmented reality should always be discussed as a visualisation or a model. For example, if an application with augmented reality shows a 3D elephant, it is essential to refer to a "model of an elephant," not to an "elephant."

1.4.3 The Principle of Adequacy

The principle of adequacy states that the goal, process, means and extent of education must be adequate to particular children's development and their individual abilities and that overloading children is counterproductive and unhealthy (it can result in discontent, demotivation, neuroses and other psychosomatic disorders). Applications with augmented reality should be presented to children as an option that is fun. They should not be used for stressful activities. Learning should be playful and should be a game.

1.4.4 The Principle of Illustrativeness

The principle of illustrativness (demonstrative teaching) refers to the need to connect the built scientific ideas and concepts to real objects by manipulating or interacting with them. It draws attention to the fact that substituting natural objects by their visualisations and projections is not sufficient. Applications with augmented reality cannot substitute the process of getting to know the world, they can only supplement it.

This means teachers should, whenever possible, expose children to real products of nature and natural objects that they can touch, smell, weigh and view at all different angles, or even throw to water, crumple, bend, or explore in other ways. Only if the object is not available, is too fragile or vulnerable (a living animal) is it permissible to use only its model, visualisation, projection or augmented reality without the object itself. In any case it seems most meaningful to present to children the product of nature as such as well as a wide range of its visualisation.

1.4.5 The Principle of Activity

The principle of activity stresses the importance of being actively involved and the danger of being passive in the learning process. Activity triggers positive emotions, being passive is boring and boredom bears negative emotions. If children are forced to passive roles, they can suffer from behavioural disorders and neuroses. In the context of the use of augmented reality, it is essential that it should be the child itself who controls the iPad or Android regardless of the price of the device.

2 Action Research

2.1 *Introduction*

Specification of the subject of this research is defined as follows:

– The problem addressed by the here-reported research study is the inconsistency, aimlessness, arbitrariness, indifference, and misunderstanding connected to the use of augmented reality for development of science literacy in preschool education.
– Contemporary pedagogical discourse in the area of development of preschool children's science literacy has recently developed its quality but experience shows that this development has not entered the teaching practice.

2.1.1 Practical Exploration – Action Research

Action research as defined by Kemmis and McTaggart (1982) "is a deliberate exploration conducted by a group of researchers (teachers) in the conditions of an educational process." The concept "teacher-researcher" has become integral part of postmodern literature on educational reform that supports professional teacher education (including teachers at the preschool level), improvement of conditions for their work, professionalization of the teaching process and development of an individual or group of learners. In the context of the current, new conditions in the system of education, teachers take on a new role in the area of monitoring school education programmes (curricula), of self-evaluation and evaluation of quality of the teaching process. Moreover, teachers, as those who are responsible for the quality of the teaching process, gradually acquire another new competence and status related to the changes in the teaching process: the competence to conduct research and the status of a teacher-researcher.

Practical research in education is one type of scientific research in which teachers study their own teaching systematically with the objective of improving its quality. This research is usually conducted by teachers (often in collaboration with a researcher) within the process of their own teaching practice. Action research reacts to the current needs of the teacher's teaching practice (sometimes only partial needs that a professional researcher does not focus on as they regard it as less important), helps to propose solutions that are tested in the classroom and, if they work, they are immediately transferred into the teaching practice. Action research should be an integral part of every teacher's activity if the teacher aims at meeting the demands of high quality teaching and developing his or her own professional competence. The methodology of the process of action research is presented in a cyclic structure, either in a spiral or a circle (Elliott, 1997; In Hernández Gil, 2007). The cyclic process consists of several stages: (1) Diagnostics of the teaching process; (2) Design of intervention (action plan); (3) Intervention and data collection; (4) Analysis and interpretation of data; (5) Illustration of the change in the teaching process (the emerging theoretical model). The given stages are conducted through reflection – action – reflection (as well as action – reflection – revision).

The decision to conduct this type of research was made on the basis of being aware that the studied phenomena are scrutinized by a person who influences the choice of methodology and the character of the research study. The subjects of this research were pre-primary teachers and their opinions on the topic of this research, which is closely connected to other subjects (children).

2.2 *Methodology*

2.2.1 Research Methodology, Methods and Organization

To handle the defined problem, the methodology of qualitative research with a corresponding design was selected. Qualitative research represents an opportunity to focus on human activity and thinking in different dimensions that contradict the conception of quantitative research (Wittrock, 1989, p. 114). It allows a relativist perception of (vision of/perspective on) the world, an individual, social life, etc. It comes out of a socio-critical paradigm (a posteriori). The objective of qualitative research is to transform or change. It uses qualitative methodology: socio-critical; action research; participative. It works with interviews, discussion/focus groups, observations as tools, methods, techniques of research. Bogdan and Biklenová (1992; In Švec, 1998) list the following characteristics of qualitative research: the natural environment, which is the primary source of data, is in the foreground; data in the form of words and images are collected; the researcher analyses data inductively. The main purpose of a qualitative researcher is to discover how people make sense of their lives; a qualitative researcher is interested not only in the processes but also in the products of human interaction. The main features of qualitative research are its intensiveness and longitudinal nature. Qualitative research relies on detailed recordings, including audio and video recordings, and attends to almost everything that is going on in the given environment. The concept "values of qualitative research" is understood as specifics of this type of research that are important, principal and full-featured for success and efficiency of the conducted qualitative research in the sense of principles of qualitative methodology. They are (according to Wittrock, 1989): Iterability (i.e., the same standard is used for generation of similar information); Systematicity – securing no interference (some kind of interference on the basis of confirmation) of our (already existing) ideas caused by a wrong selection of subjects of research and through their answers (or socially desirable behaviour); Reliability, which is related to the nature of the questions and the way they are asked – Questions must be meaningful and adequate in order to generate valid facts related to the studied phenomenon; Transparency of research tools, methods and techniques: the collection of research material and elaboration of a text must be transparent and clear to addressees of the research; and must present the research study exactly as it was conducted and must explain how the researcher proceeded in data collection, in their processing, analysis and interpreting.

Research objectives:

– To identify the impact and benefits of the use of augmented reality for development of scientific literacy in children as well as the impact of the use of augmented reality on teachers' professional development.

Research questions:

1. What should be the process by which a teacher develops pre-schoolers' scientific literacy in a complex, intentional and conscious way using augmented reality?
2. Is scientific literacy developed using augmented reality in preschool education and if so, how is it achieved?

Methods of data collection:

– Semi-structured interview and focus group discussions (Gavora, 2007; Plichtová, 2002) – collecting opinions, beliefs, explanations, knowledge of subjects involved in the research.
– Unstructured observation (Gavora, 2008) – direct observation (observing interaction of participants in the lesson) and indirect observation (observation of real situations in classrooms).

Methods of analysing research data:

– Open coding (Strauss & Corbin, 1999) – categorization, conceptualization and coding of data.
– Continuous comparison (Creswell, 1998; Kolb, 2012) – process of continuous generation of a theory.
– Selective coding (Strauss & Corbin, 1999) – grounded theory.

The data were triangulated (Ferrer & Jiménez, 2006; Mayan, 2001) in the form of systemic comparison of different researchers' opinions concerning the same data. It did not have the form of the use of more tools (methods) for creation of different data. It was an analysis of the same data using various tools.

Research sample – criteria for selection of participants in the research study:

1. Graduates from universities with a degree in pre-primary education – with respect to the research topic the participants were teachers from kindergartens where one of the declared objectives of education was development of scientific literacy in pre-schoolers.
2. Length of teaching practice ten years or more – research on development of teachers' professional competences show that the length of teaching practice allows teachers to connect declarative and experiential knowledge.
3. Home/work address: Czech Republic and Slovak Republic – the selection respected the cultural, social, demographic and ethnic diversity of kindergartens from both countries with historically similar systems of education.
4. Degree of interest and willingness to discuss issues related to the topic of this research.

2.2.1.1 *Entering the Research Project*

Before starting the research, its implementation was discussed with the head teachers and teachers in the selected kindergartens. First, we mapped the places to identify all the relevant information about conditions in the kindergartens: material-technical, organizational, and personal. Based on these findings, we adapted the conditions for conducting the research to the conditions of the particular institutions. We provided all the needed material-technical tools that were not available in the particular kindergarten (e.g., tablets, applications with augmented reality, digital cameras, etc.). Two weeks before starting the research, the teachers and parents of children involved in the research study were asked to sign informed consent forms related to the planned research and given questions for the semi-structured interview: *1. Have you come across applications with augmented reality before being addressed by us? What applications? 2. Which of them do you consider suitable for education of pre-primary children? 3. Do you use any applications with augmented reality when teaching children in the kindergarten? What applications? Why? If not, why do you not use any? Lack of knowledge and experience? Your beliefs? 4. What benefits of activities with augmented reality can you see? 5. What drawbacks of activities with augmented reality do you see? 6. Are you familiar with 4D animal or Quiver Vision? If yes, how did you use it? Was it effective?*

2.2.1.2 *Conducting the Research*

The data were collected through focus group discussions within action research at two kindergartens with preschool teachers, and five parents of 5 to

7-year-old children in two European countries, the Czech and Slovak Republics. The research subjects were asked to present their ideas and opinions in the form of answering a question asked to initiate discussion: *How can science literacy be optimally developed in pre-schoolers using augmented reality?* The research was initiated in 2017. Observations within the frame of action research were conducted in kindergartens from 2017 to 2018. The observed subjects were the teachers who took part in the discussions as well as children in the learning/play groups. The teachers participating in the educational activity "Insect" were interviewed again. In semi-structured interviews they were asked the following questions: *1. How do you evaluate the sample activity? Is it age appropriate? 2. Will you consider using this activity (with augmented reality) in activities with children in preschool education? 3. Would you be able to prepare and plan a similar activity? 4. Has your opinion on the use of applications with augmented reality in the educational process changed?*

2.2.1.3 *Research Data Processing*

Data analysis is a demanding activity, especially if a lot of research material is collected. Its elaboration requires thorough analysis and repeated returns to the terrain. Researchers are required to interpret subjective concepts possessed by subjects of the research and to conceptualize them in the form of mental abstraction in such a way that they do not diverge from the original concepts of the studied subjects. This needs time, maximal attention and responsibility of the researcher. That is why we must ask questions about such issues as freedom, consciousness, wisdom, morality and the significance of human realities on the background of socio-cultural and historical construction, whose understanding is essential for explanation of permanent, valid and socially acceptable knowledge. Permanent (as derivate of mentally elaborated experience), valid (as socially valuable) and socially acceptable knowledge is not only permanently developed by the members of a society, it is at the same time legitimized through qualitative research of human realities on the basis of constructing consent in dialogue (discourse) and intersubjectivity. By accepting that a qualitative researcher is also simultaneously the research tool, has some share in the research, and can become the subject of research, self-study (introspection) becomes a valid research tool.

2.2.1.4 *Analysis and Interpretation of Data from Semi-Structured Interviews and Focus Group Discussions*

When analysing individual protocols of statements of the research subjects in semi-structured interviews and focus group discussions, all their statements were included and the perspective of studying their potential for pedagogical-didactical development of children's scientific literacy using augmented reality was sought; answers to research questions were looked for. Conceptual labels were assigned to individual events, cases and other occurrences of a given phenomenon. By categories we mean classes of concepts that were identified when comparison of concepts seemed to indicate they belonged to a similar phenomenon. Open coding was used to carry out the processes of analysis, exploration, comparison, categorizing, coding, and conceptualization of data.

2.2.1.5 *Analysis and Interpretation of Data from Observation*

Material collected through direct and indirect observations was analysed. Events and occurrences are perceived as indicators of phenomena which get a conceptual label. Systematic reflection of professional situations, exploration of pedagogical reality and initial diagnosis based on evidence from the children in the learning/play group preceded the research activity (indirect observation). On-the-fly diagnostics based on evidence from the children from the learning/play group were carried out during the teaching process and output diagnostics based on evidence from the children in the learning/play group were conducted within pedagogical reflection on the conducted educational activity. A lot of research material in the form of video recordings and pictures and photographs was also collected in the research. In indirect observation, video recordings of educational activities were watched several times; significant elements supplying evidence on development of science literacy of pre-schoolers using augmented reality were looked for. When analysing findings from direct and indirect observations, a referential framework was abstracted (see Table 2.1). Registration of research results was evaluated on the basis of this referential framework with evaluative comments used for interpretation of results of the research.

2.2.1.6 *Entering the Teaching Process and the Teaching Process Using Augmented Reality*

Teaching activity: Insect

Specific goal:

– On the basis of hands-on experience and practical activities, to build a positive relationship to natural environment and to recognize insects as a part of nature.

Partial goal:

– Focus on characteristic properties of insects and to learn about their life in nature.

Motivational strategy:

– Direct induction of situation using an application using augmented reality.

Communicative situation:

– Interview, discussion, and analysis of problems that arise.

TABLE 2.1 Diagnostics presence of development of scientific literacy of children in the augmented reality supported teaching based on evidence (excerpt)

Description of a didactical situation in an educational activity	Presence of development of science literacy of children in the augmented reality supported teaching
– *Stage of evocation* – the teacher asked the children to present their knowledge of insects verbally. Each child was given enough space to construct ideas connected to the concept of insects. The teacher steered the discussion in a way to make the children's preconceptions contradict the new information or facts with the purpose of bringing about a cognitive conflict. She also stirred the children's internal motivation by discussing with them propositions on how to carry out the topic of the activity. Children's ideas and proposals were recorded on the blackboard. At the same time the teacher was diagnosing the children's conceptions of insects (by categorizing them) – thematic categorization (initial evaluation) (see Figure 2.7). The children were creating a conceptual mind map of their initial concepts, they were expressing their (own) opinions. The teacher supported children's collaboration by creating conditions for it – this is *the pre-active stage of teaching.*	 FIGURE 2.7 Thematic categorization/ initial evaluation The children verbally express their ideas on how to carry out this activity. They want their teacher to record the proposals. The children make decisions about individual activities that will be carried out within the whole activity. The children set rules about how to carry out the game together with their teacher. The teacher gave the children an opportunity to experience something and to reinforce the new knowledge by hands-on experience. The children acted and made decisions autonomously. The teacher's opinion was not determining for the children's activity in the game. The children developed the game spontaneously; they were autonomous because their activity was based on their own solutions.

(*cont.*)

TABLE 2.1 Diagnostics presence of development of scientific literacy of children in the augmented reality supported teaching based on evidence (excerpt) (*cont.*)

Description of a didactical situation in an educational activity	**Presence of development of science literacy of children in the augmented reality supported teaching**
– *Stage of becoming aware of meaning* – the children developed the topic in specific forms. They were able to discover spontaneously how they should do something. The teacher developed their digital literacy with an individual approach using tablets and worksheets with a black and white printed marker. The marker in the form of a picture was scanned with the tablet by the children on their own. The teacher also asked questions that served as the basis for constructing new knowledge in the area that was topical and interesting for the children (thematic conceptualization) (see Figure 2.8). Children discovered autonomously that the tablet had to be held in a certain distance from and direction to the worksheet to see the 3D object projected above the marker. Then the children saw a virtual object instead of the marker on the display. Specifically, it was an easily identifiable and easily generated picture on the coloured worksheet on the topic Insect. The children followed their game objectives and in cooperation with the teacher	 FIGURE 2.8 Thematic conceptualization/ on-the-fly evaluation The children carry out various activities (that they have proposed) while gaining new knowledge. They were able to ask challenging questions, constructive solutions to which they were looking for, because reshaping asks for functional zones and turns (socio-cognitive conflict) and enough secure space and time. They asked questions autonomously, thought about them and carried out activities in which they were involved. The children had space for self-realization and developed the game. They solved the problems independently, e.g., in the case when the 3D and 4D objects did not appear.

(*cont.*)

TABLE 2.1 Diagnostics presence of development of scientific literacy of children in the augmented reality supported teaching based on evidence (excerpt) (*cont.*)

Description of a didactical situation in an educational activity	Presence of development of science literacy of children in the augmented reality supported teaching
they proceeded in their work on the educational problem – thematic realization/preliminary evaluation. The teacher identified what each child can manage – this is *the interactive stage of teaching.*	They were manipulating with the tablet, as it allowed orientation in space to such an extent that they could view the object from all perspectives. The children carried out the following activities: they proposed, discussed, offered alternatives, approved, voted on the final product.
– *Stage of reflection* – in the final stage of the educational activity the children together with their teacher gave feedback on the stated educational problem by creating a partial product (final evaluation) (see Figure 2.9). Children's reflection (self-assessment and assessment) was connected to their development of scientific literacy and also of digital literacy through augmented reality. The children made independent decisions about their activity but partly needed their teacher's assistance. The teacher's evaluation was related to partial goals defined for the educational activity. The teacher respected each child's personality and supported them in decision making and assessment. At the same time, she provided enough time and space for the activity to be carried out. In the activity she put emphasis on communication and information exchange – this is *the post-active stage of teaching.*	 FIGURE 2.9 Thematic realization/final evaluation The children depicted the links between the given concepts. They created a conceptual mind map autonomously. If needed, they asked their teacher for help. The teacher supported the children by asking questions that developed critical thinking. The children were able to look for their solutions. They presented the gained knowledge autonomously and evaluated the course of the conducted activity.

Experimenting with the topic (*what activities related to the topic will be used in experimenting– how the subject matter will be experimented with – how the topic will be explored by the participating teachers and learners*)*:*
– What is an insect? What does an insect need to live in nature? Why are insects an important *part of nature?*

Situation of experimenting:
– Strategy of stimulating questions, problem-solving methods, and practical activity.

Developmental primary activity:
– Development of linguistic competence, stimulation of optimal behaviour respecting the particular habitat, stimulation of verbalization and circulation of ideas in a discussion with the help of relevant and suitable questions (not general questions) targeting explanation of some mental plan (what we will do, why we will do it, how and where we will do it, with whom or what we will do it, etc., while using the application with augmented reality on the topic "Insect"). To use acquired knowledge in the context of family and society as an incentive for follow-up discoveries. Children are divided into groups and work on various aspects of the topic with the help of their teacher (if needed).

Formalization, representation and symbolization of experience:
– to solve a problem in connection to a given condition.

Indicators for evaluation of observation:
– the child should be able to recognize insects in the surrounding environment,
– the child should be able to justify the importance of insects in nature,
– the child might know, for example, the process of getting honey.

Developmental integrational skills:
– manipulation with tablet,
– getting to know activities when using applications with augmented reality,
– cooperation on and collaboration in activities.

Activities:
– selection, proposing, considering, sharing, manipulation, discovery, discussion, communication, pondering, justifying, listening to, asking, cooperation, collaboration, determination, classification, and assessment.

2.2.1.7 *Elaboration of Research Material*

Elaboration of typology was conducted as a stage of the qualitative analysis of the conducted research. As Woods (1987, p. 160, in Kostrub, 2016, p. 95) states, "it is a special form of description which requires clearing of a large amount

TABLE 2.2 Referential framework presence of development of scientific literacy of children in the augmented reality-supported teaching based on evidence

Integration	General framework: children are fully self-reliant; they need no help. They develop fully. They act freely on the basis of their own considerations in accordance with the collectively defined rules. *Framework of a specific activity: children ask other subjects in their play group to enter into some game, they maintain interaction in the game, terminate the game, evaluate the game independently, and provide feedback on the game to other subjects (children and teachers).*
Contextualization	General framework: children are becoming self-reliant; they act autonomously but are not fully independent yet. When acting they ask their teachers for specific help. *Framework of a specific activity: children together with teachers set conditions and rules for the game, while playing they ask their teacher for help, they evaluate the game partly independently and give feedback on the game with minimal teacher's support.*
Decontextualization (socio-cognitive turn)	General framework: children learn to act independently. They alternately ask for their teachers' help and act autonomously in which case they ask questions to check whether their actions are correct. *Framework of a specific activity: children try to act autonomously but they ask teachers to give them feedback on their activity. Their acting is autonomous but their decisions are not. They wait for the teachers' opinion on what to do and/or how to do it. The teacher proposes conditions of the game to children.*
Coordination of points of view	General framework: children are partially dependent; their autonomy is minimal. In most of their action they ask for help, confront their activity with their teachers' opinion while the teachers' opinion is decisive. *Framework of a specific activity: children act on the basis of their teacher's opinion, which is determining for them.*

(*cont.*)

TABLE 2.2 Referential framework presence of development of scientific literacy of children in the augmented reality-supported teaching based on evidence. Source: author's own elaboration (*cont.*)

	The teacher defines the particular course of the game and at the same time encourages children to help her. Children are not supported in autonomous decision making.
Decentralization	General framework: children are not autonomous; they are fully dependent on the teacher's decisions and they wait for their invitation and verbal as well as non-verbal instruction, presented patterns and already made decisions. They wait for feedback on correctness/incorrectness of their actions. *Framework of a specific activity: the teacher defines conditions of a particular game according to in advance stated rules. The teacher's opinion is determining for children's activity. Children act and make decisions dependently.*

of materials, analyses and massive description. They are forms of description (also in the sense of referential frameworks), they can help to understand some area of social activity" (see Table 2.2).

Continuous comparison was conducted as a stage of qualitative analysis of the conducted research. When applying the method of continuous comparison, as Kolb (2012) warns, "the objective is not to verify universality or to confirm causes or other input data. This process provides saturation of the needed information. The goal of application of the method of continuous comparison is not verification but generation of a theory. What is studied is the size and saturation of some information until the right level of saturation is achieved." Glaser and Strauss (as cited in Kolb, 2012, p. 83) claim that the method of continuous comparison has the following levels: comparison of events useful for some category; integration of categories and their properties; definition of a theory; and conception (writing) of a theory. Selective coding was conducted within the frame of the conducted research as the final stage of qualitative analysis (the process of construction and validation of categories). The central category abstracted from the research was the category "intentional support of development of scientific literacy using augmented reality."

2.2.1.8 *Outcomes of the Conducted Research and Their Interpretation*

The perspective of perceiving the potential of pedagogical-didactical development of science literacy of children using augmented reality from the point of view of the subjects involved in the semi-structured interviews and focus-group discussion within the frame of the research, is presented graphically (see Figure 2.10). The practicing teachers (as well as parents whose children were involved in the research) were an essential source of knowledge because it is them who can evaluate teaching activities and the whole teaching process from their point of view as something no longer acceptable, asking for some change or requiring some practical answer in the form of an adequate solution. Reflection as a form of feedback was crucially important to understand what was happening in the research:

- For description of activities of subjects, for grouping of ideas and follow-up, more comprehensive ideas on what was experienced and understood.
- For analysis of complex experience from the research and for making conclusions from what was gained and especially for analysis of everything that had happened.

Despite the interpretational tangle of statements, it must not be forgotten that children are here, they are part of the adult world to which they must adapt;

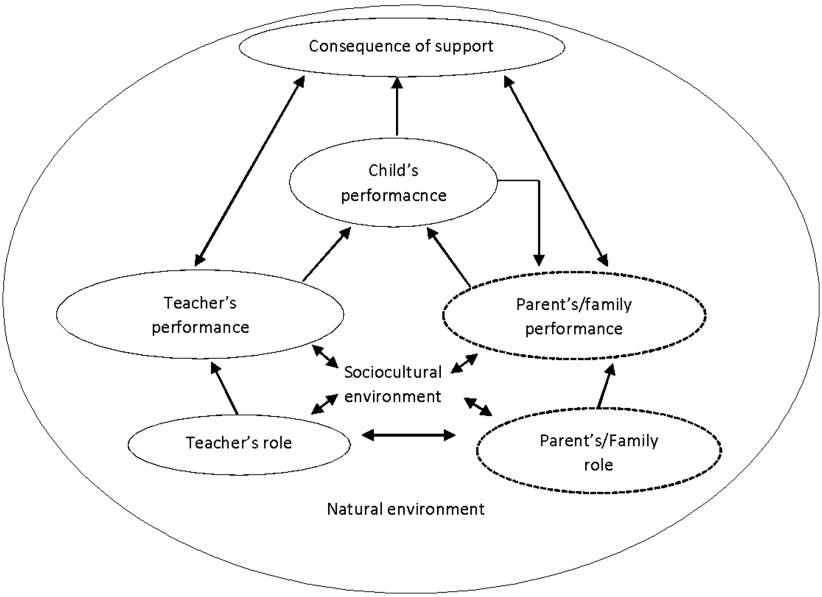

FIGURE 2.10 Development of scientific literacy in pre-schoolers using augmented reality with respect to the point of view of research subjects

they must develop qualities typical for the adult population. Parents' social responsibility and teachers' professional roles are to support development of the scientific literacy of children as a part of their cultural literacy, also using augmented reality. What proves to be problematic is the discord in perception of importance of this support, of its profile and extent, etc. Another discrepancy is between the parents' and teachers' educational approaches by which they encourage, support, maintain, or block children's autonomous activity when using applications with augmented reality for development of science literacy. It is essential to realize that many discursive and cultural practices ask for children's autonomy and self-reliance, especially in the current postmodern society in which children live. That is why urgency of the need to change the perspective to children is emphasised. Explanations of children's activity in the perspective of teachers involved in the research are related to mental representations (as well as socially acceptable representations) and how these actors, the teachers, personally interpret it. The activity of one actor depends on the quality of their interaction with other actors. Analysis of this interaction and its consequences in the perspective of the actors themselves allows interpretation of this interaction and making deductions.

The outcomes of the conducted research from the direct and indirect observations of the teaching process using augmented reality for development of science literacy in learning/play groups of children and from semi-structured interviews and focus group discussions of the involved subject are shown graphically (see Figure 2.11).

In current pedagogical/didactical practice, there is not enough support of development of scientific literacy of children with the help augmented reality. The given support is quite limited (possibly insufficient with respect to the developmental potential of the educated children) and has the form of carrying out limited and unequivocal demands, requests, instructions, directives, and manipulations, etc. – teachers do not support children explicitly but only implicitly (randomly, unconsciously, intuitively, and accidentally, etc.). That is why it proves to be essential to change how pre-primary teachers perceive the use of augmented reality in teaching when developing science literacy in pre-schoolers.

2.2.1.9 *Notes from the Czech Republic*

The head teachers from both Czech kindergartens were rather sceptical and asked whether it was suitable at all to use augmented reality in preschool.

However, attention of both groups of children was seized by the application Animal 4D+. The children spent most time experimenting with which animals will actually eat bananas.

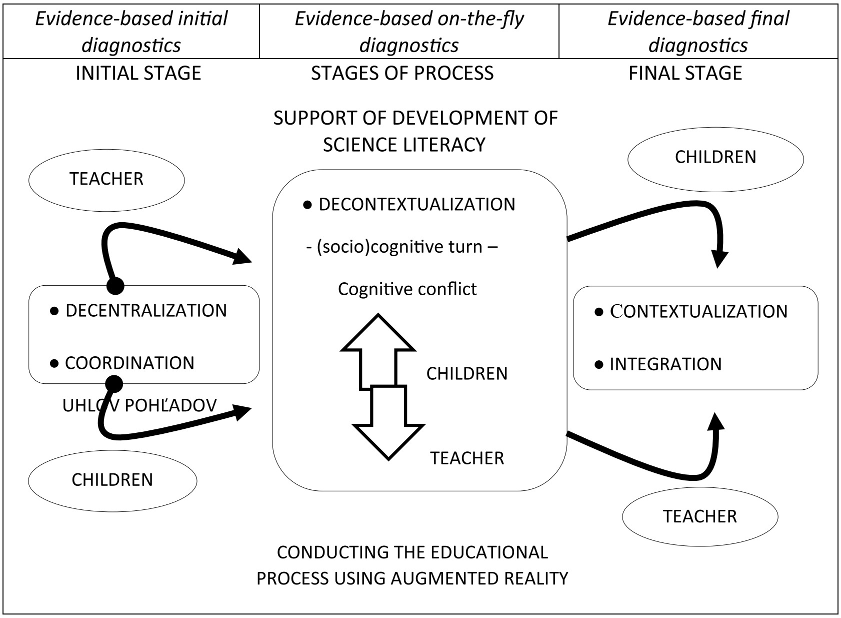

FIGURE 2.11 Position of the teacher and children recorded in time and space presence of development of scientific literacy of children in the augmented-reality-supported teaching based on evidence

The teachers concluded that the application was an interesting supplement, making the learning process special. However, they could not imagine using it regularly in their teaching.

They expressed their fears that the children would get the feeling animals were toys and would underestimate the real danger if encountering the real animal (e.g., being bitten by a dog). Namely (For the second thing I see it as dangerous that children could get the feeling it was absolutely safe to go near any animals. For example, an elephant looks like a small cute animal that we can hold in hands, a bee like an animal that can be stroked, etc.).

They also expressed their worries about the effect of distortion of proportions.

When some of the younger children were manipulating the tablet, the teachers were worried about the possible damage to the tablet and also to fellow students: one three-year-old child used the tablet as a weapon for hitting another child's bottom.

Another obstacle mentioned with respect to its use in the kindergarten was the language barrier: as a Czech version of the application does not exist yet, the children cannot learn more about the animal or cannot use the other opportunities the application offers.

Having been introduced to the application "Insect" the teachers stated that in this case they saw meaningfulness of applications with augmented reality.

2.3 *Findings*

The conducted research helped us get a repertoire of opinions on and attitudes to the selected issue from the community of pre-primary teachers in the Czech Republic and Slovakia, two different countries with similar systems of education. Interpretation and discussion helped us identify a spectrum of opinions on and views of: (1) What should be the process that would lead to a complex and intentional development of scientific literacy using augmented reality in preschool education? (2) Is scientific literacy of children in pre-primary education developed using augmented reality and if so, how? These opinions and points of view are illustrated by professional experience. At all research stages, the research sample consisted of teachers from different cultural, social, demographic and ethnic backgrounds who were interested in the research and were representatives of different kindergartens with respect to their geographical position in both countries. The subjects of our research in both countries spoke of the need for intentional didactical development of scientific literacy with the use of augmented reality similarly. The researched phenomena were present in opinions of all subjects.

Another research finding is that the research subjects (preschool teachers) started to support development of scientific literacy in preschool children by using augmented reality deliberately while conducting the research. What was crucially important in this process on the teachers' part was their creativity, imagination, sense for details and complex perspective on what can be done about teaching and in teaching. It was also confirmed that the learning and teaching processes are interrelated and complementary. The principles accepted and used in teaching were freedom, decision making, activity, guidance, responsibility, and self-assessment. The principles used in individual and collective learning were role-play, and discussion, forms of cooperative and collaborative learning. The priority of intentional didactical support of development of scientific literacy of pre-schoolers by using applications with augmented reality was autonomous and socio-constructivist understanding of the teaching process was opposed to the transmissive (academic) conception of teaching. The transmissive teaching model was identified in the initial stage of the research. Decontextualization was identified between the initial and final stages of the research (see Figure 2.11 and Table 2.2) – a socio-cognitive turn, which points at the inseparability of social and cultural aspects in interpersonal interaction and transaction in the teaching process, was observed in the phenomenon of socio-cognitive conflict (which is important to bring about socially and culturally conditioned conceptual change). The teaching process used various forms of creative mental activity which were derived from social and cultural contexts in the process of their mutual sharing – social, cultural, or natural environment. In contrast, the teaching model built on socio-constructivist theories that was identified in the final stage of our research uses strategies in which the teacher gives more space to children.

3 Conclusion

Applications with augmented reality bring about entirely new opportunities but also put new demands on teachers and pupils.

If the teacher selects suitable applications and adheres to didactical principles for their use, applications with augmented reality bear high potential for development of scientific literacy in general and the preschool age is not an obstacle. However, since manipulation with a tablet is difficult for preschool children, it may be more appropriate to use special glasses for augmented reality rather than tablets.

Acknowledgement

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Notes

1 In fact, they are models and are used as models but teachers rarely consider them as such.
2 See https://itunes.apple.com/cz/app/anatomy-4d/id555741707?mt=8
3 See https://forio.com/simulate/e.pruyt/rabbits-and-foxes/overview/

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