Chapter

Emergent Chemistry: Using Visualizations to Develop Abstract Thinking and a Sense of Scale within the Preschool Setting

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Abstract

This chapter is a summary of 5-years of research regarding children's emerging abstract concepts. A longitudinal study focusing on children's conversations during a series of activities with a chemistry focus was designed and implemented. Results show that practical experience with magnifying glasses, microscopes, and the deconstruction of several items did not provide enough backdrop for the children to imagine what an even smaller world would look like. Instead, the children applied their experiences from the macroscopic world to describe what they saw. It was not until aminations, zooming in from the macroscopic to the atomic and molecular levels were used that the children's concept of small began to develop. Results show that the next stage of concept development, besides using descriptions from everyday experiences was the realization these were new experiences, that it was in fact something new they were seeing. Animation technology also helped the children realize that atoms and molecules are everywhere in everything, suggesting that the time elapsed between the transition from the macroscopic level to the submicroscopic level also provided the children with a sense of scale.

Keywords: preschool education, abstract thinking, scale, natural science, chemistry

1. Introduction

Preschool education in all countries has one general goal in common. That goal is to provide children with a broad experience base. This is done since experiences are seen as the foundation of learning, creativity, and imagination. Learning can be seen as a change in previous experiences and Vygotsky proposed that imagination is based on experiences [1]. A proposition suggests that it may be difficult for us to imagine something which we have no experience of. Creativity was as also described by Vygotsky as, new ways to combine experiences. Indeed, learning, imagination, and creativity are some of the intended outcomes of preschool education.

2. Preschool education

Learning can be viewed from different perspectives. A general perspective was provided by Piaget who thought of learning as a change in previous experiences. Piaget [2] then continued to describe learning as being possible within different stages while Vygotsky used another perspective and described learning as more situationally bound. Vygotsky saw learning as not only occurring in all instances but also dependent on what was possible in every situation. He saw learning as occurring in the space between the real and the ideal form. Today researchers use the word the present form instead of the ideal form to emphasize that the social world surrounding a child may not in fact be ideal [3]. The real form is the child's current experiences and the term present form is used to describe what the social environment surrounding the child contributes.

How experiences are formed was also described by Vygotsky with the use of the concept of perezhivanie. The concept of perezhivanie [4] provides a perspective where we all are seen as viewing the world through our own personal prism. A prism that is formed by our previous experiences the prism determines what we notice and how this information is then interpreted. Suggesting that our current experiences affect our learning of new experiences, and our new experiences will affect our current experiences (see **Figure 1**).

Those experiences that are seen as having the greatest impact are those who are emotionally connected. If the theory is placed on a time scale such as a lifetime, then it suggests that emotional experiences will impact what we learn but also that our learning becomes more personalized as time passes. An interest in birds will cause us to focus more on birds something that will make us learn more about birds, something that in turn will make us notice more details regarding birds. If this is the case, then this perspective provides us with three important conclusions regarding preschool education: the first one is that the present form must include a manifold of new experiences, and the second is that it is important to intentionally create positive experiences since they will affect lifelong learning and the third is that activities should be designed for individuals. This research takes inspiration from a cultural-historical approach [5] that involves both cultural and individual aspects.

What is/should/could be included in a broad experience base within preschool education is today argued in the research literature. Most if not all authors agree

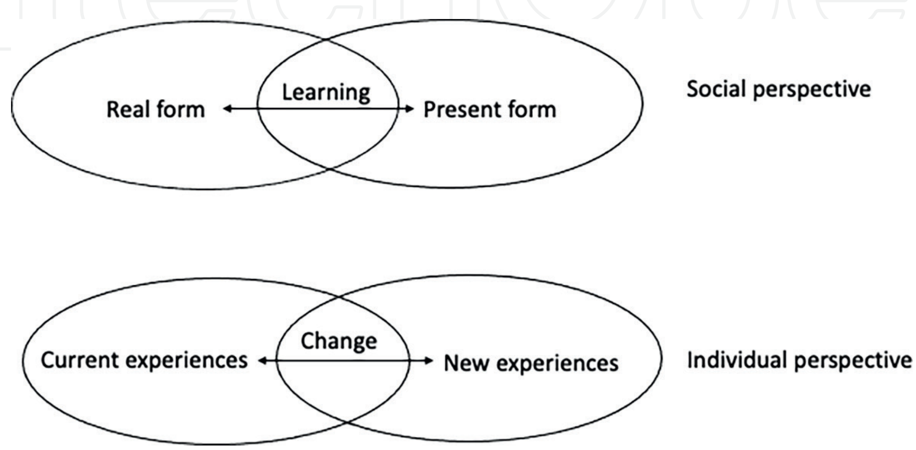

Figure 1.
A general overview of the difference between the social and individual perspectives when the concept of perezhivanie is used.

on the fact that the content of preschool education should meet the children's own interests and needs. For some, this approach means to follow the children's lead and expand on their own interests [6] while others see it as actively introducing children to new experiences by conveying content indirectly through play [7]. In practice, most preschool education is of course a mixture of these two counterparts. As it would be difficult to only follow the children's lead since they all have different experiences so what is following the experiences of one child is staging a new experience for another child.

The content of activities in preschool education is also under scrutiny, there are those authors who argue that preschool education should be free of any academic content [8] while others see preschool as an opportunity to provide children with play-based activities with content that are designed and could well be seen as academic depending on our definition of what is included in academic content. The one thing that most authors agree on is that preschool education should at all costs avoid schoolification. Schooloification is a term used for describing a more direct transfer of academic school knowledge to the preschool level. The key to avoiding schoolification is to analyze children's activities and allowing their questions and current focus, that is, to be the force that drives experience building [9] regardless of whether the content is deliberately introduced by the teacher or not.

2.1 Development as a case of emergence

When researchers describe learning in the preschool context is often described in terms of emergence [10]. When using the term emergence focus is placed on children's own version of content. It is a version that is not evaluated for its correctness but instead because it provides clues that help us provide a more supportive preschool environment. The use of the word emergence also recognizes that what research can describe are only small parts/glints of the process of learning.

2.1.1 Content of preschool education

Today natural science is a part of the experiences that most preschools provide. It is in fact difficult to avoid natural science content in preschool as children have a natural tendency to explore their surroundings [11]. And as natural science is found in all aspects of the immediate world surrounding the child, i.e., in the material-, biological- and cultural aspects it is a content that is difficult to avoid. The goals for this content can be found on both individuals as well as societal levels. On the individual level, the goal is of course to meet individual children's own curiosity and to build positive experiences of science [12]. Positive experiences in science are important for creating self-confidence, that is, positive subject identities so that children feel confident that they are good at science. Indeed, motor active hands-on activities contribute positively to positive attitudes toward science [13] providing a stronger positive subject identity. Another goal is to create cultural motives [14] and thereby making science a natural part of the child's everyday life. On a societal level, the goals include creating interest in the natural environment to develop children's environmental awareness to build for a more sustainable future [15].

From the perspective of learning a natural science content, an early introduction to the concepts and words that natural science is comprised of is seen as beneficial, since many of them take a long time to get familiarized with [16]. Indeed, research on children's science learning on a general level can be separated into categories:

development of abstract thinking [17], development of words, concepts, and their content [18], developing understanding of processes and transfer of knowledge/ideas between contexts (near- and far transfer) [19] as well as the process of science inquiry [20]. Most of these studies include topics that could be categorized into biology and physics. Very few studies have focused on chemistry and how a more chemical content could be transferred into a preschool environment [21–24]. This is even though so many of our chemical methods can be found in the child's immediate surroundings and explored through hands-on experience. One example is separation methods such as filtering something that we do on a daily basis while: separating pasta from water, ions from water, tea leaves from the water, ground coffee from water, preventing pieces of food from entering the pipes in our kitchen or strands of hair from pipes in the bathroom, light from entering a room, butterflies from the air, fish from the water, or preventing sound from entering our ears. Another reason why chemistry should be a part of the preschool environment is because the single most important feature of chemistry is imagination. Chemists have spent centuries trying to imagine what an abstract world, the submicroscopic level could possibly look like and how its different parts combine and dissembles. When taking this perspective, it becomes interesting to explore children's abstract thinking and how they imagine the submicroscopic world, and what sort of circumstances we need to create in a preschool environment to begin this abstract and imaginative journey.

2.2 The development of abstract thinking

Abstract thinking is something that has been defined by many authors. Some examples of these definitions are; the process when children can represent reality by using a representation, for example, an object, that is, symbolic representations, "thoughts that are not immediately connected to the environment" [25]. Or, detaching from the concrete world while still maintaining a connection to it through representations. The first one to define what a representation is may in fact have been Aristotle who stated that the world and the world as we describe it are not the same things. The way we can view the emergence of children's abstract thinking is through their use of objects and symbolic representations in play, where a stick can become a sword or the symbol X on a map can represent a hidden treasure.

The development of abstract thinking, that is, real-world experiences to abstractions thereof has also been described by a few authors. These descriptions vary in specificity from the general to the more specific and from suggesting causes for development to suggesting how this development occurs. When turning toward causes for the development of abstract thinking research suggest that children have a natural tendency to seek patterns in their real-world experiences to generalize the experiences [26]. Suggestions for how this development occurs date as far back as Piaget (1953). Piaget described the development as including three parts: action, symbolic mediation, and then later abstract thought. More specific description has also been suggested. One of these descriptions separates this development into four different parts: i) motor, ii) symbolic representations, iii) functional dependency, and iv) thought. Functional dependency [27] is here used as a category to describe, children practicing making connections between reality and abstract representations as being one of the first steps toward abstract thinking. A stage in development that becomes specifically interesting to further explore as it affects how the representation is used and gives us clues to how natural connections between the representation and the real world are formed, and what they may look like.

2.3 Abstract representations

Here it is not the children's own representations of experiences that are in focus but instead how children being to understand the representations that we use in our daily lives, our cultural tools. When turning to the line of research that focuses on exploring already made representations, they are viewed in the perspective of the dual representation strategy [28]. Were a representation is seen as both a representation of something and at the same time as an object, in itself. The different types of representations that have been described in the early-years literature include representations such as maps, images, and scale models [29], or interactive representations, such as gaming or educational TV programs [30]. Research on young children's use of representations shows that the connection between reality and representation is difficult for young children. Something that has been shown through experiments where children have been presented with scale models of a room, a toy was hidden in the room as well as in the scale model, and the quest given to the child was to find the hidden toy in the real room. For children as young as two years old, the success rate of this quest increased when the idea of a shrinking machine was introduced. The shrinking machine gave the children the impression that the scale model was in fact the real room that had just become smaller [29]. The same result was described in other studies where the scale model was replaced by a video of someone hiding a toy. The rate in success of finding the toy was higher when a window frame was placed around the image of the video giving the children the impression that they were looking into the room itself. It has also been shown that children's use of representations improves if the child does not get to play with the object itself before it is used as a representation. A result suggests that the child's familiarity with the object causes them to place their focus on objects instead of the object as a representation [28]. This result suggests that "removing the duality" makes representations easier for young children to understand.

Research result deriving from young children's use of interactive games and activities adds additional levels of complexity to the use of representations. The more sophisticated interactions become less useful in terms of content if the actual interactive part is difficult to handle as the child's focus is then placed on the object of interaction instead of the intended outcome. Similar results have been seen in for example laboratory work for much older learners where unfamiliarity with equipment changes the intended focus of the laboratory from the intended phenomena to the material itself [31]. When the representation comes in the form of a photo, then young children seem to notice that there is a difference between photographs and real objects [32] but they do not seem to understand this difference something that can be seen when children try to remove items from a photo [33]. When maps are used or scale models as above scale become an additional problem. Young children have difficulties seeing the lines on a map as roads since the lines are much too small to fit a car [34].

Research results also show that it is important for a continuous transformation between the concrete and the abstract, to facilitate functional dependency and abstract thought [35]. It is in fact not until the last decades that technology has made it possible to provide more realistic representations than simple images and molecular models, on a macroscopic scale. Some researchers see visualizations as being powerful since they have the ability to make us think in visual terms instead of in abstract terms, [33] thereby providing us with a kind of immediate reproductions to better support imagination.

So what do we know about children's descriptions of the abstract world? Research also tells us that children use metaphors, analogies, and similes (it looks like… something that they recognize) to describe unknowns [36]. These expressions can in themselves provide us with information to better support our youngest learners [37] as they are highlighting specific aspects, show us interpretations and become means for sharing feelings.

2.3.1 Project design

The results presented here are a summary of a longitudinal project, an intervention, designed to explore the development of children's abstract thinking. The intervention was designed as, an educational experiment where activities were designed and analyzed before the next activity was designed to ensure that it was the children's own interest that was the driving force behind the activities. These precautions were made to ensure the children's own interests were in focus and to avoid schoolification. The development of the concept of small was chosen although several other topics could just as easily have been applied. The reasons for this choice were emergence. Exploring children's emergent science and here, especially children's emergent chemistry means that no evaluation of the scientific correctness of the content was made. Studying emergence then means simply exploring children's own versions of scientific content. Using the development of the concept of small as an entrance also meant that we studied actual emergence since none of the children had previous experiences of levels below the macroscopic lived world, something that was also established in the first set of activities. Means that our findings would be a result of our activities and results would show the first-time experiences of the submicroscopic world. Also transfer between different contexts could also be studied as the interventions initially were the only source of information.

To provide the children with a backdrop for the science activities the activities were framed within a story. The story of the king and his royal family was derived from visits to the preschool and by observing the children's free play. The story began with the king's birthday where he was given a magnifying glass and began to explore the world around him [21].

3. Results

After the first activity, it was clear that none of the children had the experience of small things on a level below the macroscopic level. The smallest thing that they could imagine was on the level of baby bugs. When the interventions moved along it was clear that the story of the king quickly became superfluous. When the researcher entered the preschool, all children attending ran up to her and asked what are we doing today? Suggesting that the items and the researcher were enough to catch the children's attention [21]. This result may not seem significant, but it may also help preschool teachers to make science activities more easily accessible since the results support the idea of the design of play-based activities with an intended content. As the intervention proceeded the magnifying glasses were replaced by microscopes, but the children's descriptions remain at the level of similes. The size difference in children's descriptions moved from baby bugs to pea flour (which was the word they used to describe the content of peas). Mortared sugar was described as ice blocks and the connections made were toward lived experiences, such as brushing teeth and why sugar is harmful to your teeth. All interventions so far did not bring about imagining a world that could not be seen. The choice to introduce zooming-in videos was made to provide as real experiences of the atomic-molecular level as possible. Zooming-in videos of a range of different everyday items were introduced to the children. An experience that was appreciated by all the children. When the molecular level was reached, similes were used once again by the children "look at the meatballs." After a few zooming-in videos that ended in meatballs, the children realized that the meatballs were everywhere, in everything and that it may not be meatballs at all but instead something else. At this point, the researcher labeled them as molecules and atoms [22]. These results support the perspective of the dual representations. The animations were as realistic as possible something that may have assisted in the development of this particular form of abstract thinking as results suggest that removing the duality of the representation makes them more easily understood by children [28]. When using the perspective of functional dependency to look at the actual connection that the children made between the representation and the real world. The connections were based on similes and the change did not begin until the children had been exposed to several animations. A result that also supports the idea of continuous transformations between the lived world and the representation is required [35]. There is no doubt that animations provided these children with new experiences of a world that normally is beyond sensory experiences. New experiences that may be the base for future imagination and creativity. This is a very important result for educational settings as images of atoms and molecules naturally are macrolevel representations and moving animations this may so far be the only way to provide relatively realistic experiences of the submicroscopic level something that may support learners at all educational levels. If the concept of perezhivane and its effect on lifelong learning is valid, then experiences like this may have long-lasting impacts on a personalized learning process.

4. Conclusions

The results show that developing abstract thinking from motor interaction of the macroscopic world with magnifying glasses and microscopes did not induce children's imagination of what came next. Providing visual experiences of the submicroscopic level did show the next stage in concept formation: the realization that it looks like something … but it is not… brought gave rise to a concept by the researcher labeling the experiences. This concept together with "they are every was in everything" suggests that the children to some extent understood the scale of the atoms and molecules, at least to the extent that they are small enough to be inside things. A result that supports Vygotsky's idea that experience is a base for imagination. This is an example of functional dependency in the way the concept has been interpreted in this context. The fact that the children saw several data animations of different items supported their connections between the animation and reality since it was not until several animations had been seen that the separation between their experiences and the animation began to show. Suggesting that connections need to be made on several occasions.

Acknowledgements

This research was funded by the Crafoord Foundation (Refnr: 20200712).

Conflict of interest

There are no conflicts of interest.

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