Ice melting in Early Childhood Education: a case of the designing and implementing a STEAM Project about water state changes

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ABSTRACT

This paper examines the water state changes in Early Childhood Education. Particularly, the designing and implementation of STEAM activities regarding the melting of the ice is presented with the use of the Engineering Design Process. It also presents the results of this qualitative study where 15 children between five and six years old engaged in pre-and post-tests as well as in a 4-staged STEAM teaching intervention. The children followed four stages to solve a real-life problem, firstly they identified the problem and then developed ideas, and solutions designed their own solutions, and tested them while presenting the final outcomes at the end. The analysis of the results revealed that children at this age are able to understand the water state changes and link the ice with water under specific designated STEAM activities.

KEYWORDS

Science, Early Childhood Education, STEAM, water state changes, ice, melting, Engineering Design Process

RÉSUMÉ

Cet article examine les changements d'état de l'eau dans l'éducation de la petite enfance. En particulier, la conception et la mise en œuvre d'activités STEAM concernant la fusion de la glace sont présentées à l'aide du processus de conception technique. Il présente également les résultats de cette étude qualitative dans laquelle 15 enfants âgés de cinq à six ans ont participé à des pré-tests et à des post-tests ainsi qu'à une intervention pédagogique STEAM en quatre étapes. Les enfants ont suivi quatre étapes pour résoudre un problème de la vie réelle : ils ont d'abord identifié le problème, puis développé des idées et des solutions, conçu leurs propres solutions et les ont testées tout en présentant les résultats finaux à la fin. L'analyse des résultats a révélé que les enfants de cet âge sont capables de comprendre les changements d'état de l'eau et de faire le lien entre la glace et l'eau dans le cadre d'activités STEAM spécifiques.

MOTS CLÉS

Sciences, éducation de la petite enfance, STEAM, changements d'état de l'eau, glace, fusion, Engineering Design Process

INTRODUCTION

Science in Early Childhood Education is a broad research field that examines children's ideas and thinking about various concepts and phenomena. In the last decades, STEAM education is a new research field that promotes an interdisciplinary approach between Science, Technology, Engineering, Arts & Mathematics. Especially in Early Childhood Education, it seems that the STEAM approach could be implemented for a large variety of learning areas including Linguistic arts and Language learning. Thus, it is important to study children's pre-conceptions, ideas, and representations. In general, research progress on mental representation studies resulted in a reorganization of the thinking of young children which is based on different theoretical approaches (Ravanis, 2017).

In the last decades, STEAM education is being introduced in early childhood education to introduce a variety of topics from science and mathematics to robotics and engineering concepts. It began as an acronym of Science, Technology, Engineering, and Mathematics (Bybee, 2010) and the component of Arts was added later to enhance creativity (Sousa & Pilecki, 2015).

In this research, the design process of a teaching intervention about water state changes and the water cycle in nature is being discussed. The aim of the present project is the design and implementation of a STEAM project in early childhood education about the water state changes and the water cycle in nature. This project consists of 5 phases: a) Ice melting, b) vaporization, c) condensation, d) precipitation, and e) the water cycle in nature.

More specifically, the first phase of a STEAM project about ice melting is being presented. Firstly, the theoretical framework and the methodological approach are discussed. Then, the results are analyzed and finally, the conclusions are presented.

THEORETICAL FRAMEWORK

Ioannou et al. (2023) literature research about water state changes and the water cycle in nature highlighted the familiarity of young children with the evaporation of water, melting of ice, and other similar phenomena and categorized the existing research into two categories. The first research category emphasizes individual state changes and the second category on the water cycle in nature.

In general, despite the difficulties in learning and understanding these notions by young children, it seems that students in Early Childhood Education have interesting experiences with thermal phenomena and could approach scientific knowledge with appropriate teaching methods (Ravanis, 2017). In addition, learners need to connect the notions with everyday life and their experience with opportunities to apply the new knowledge to solve problems (Smith & Samarakoon, 2017).

Early childhood science education covers a variety of concepts and phenomena such as heat transfer phenomena (Kaliampos & Ravanis, 2019; Pahl et al., 2022), thermal insulation (Fragkiadaki et al., 2021), thermal expansion and contraction (Ravanis et al., 2013), the use of the thermometer (Cain & Lee, 2020; Kampeza et al., 2016) and, in general, the temperature (Hindarti et al., 2021; Pahl et al., 2022).

Research has already been conducted about the water cycle with activities about evaporation and mental representations of children from five to eleven years old (Bar, 1989; Russel et al., 1989) or mental representations of young children from 5 to 6 years old concerning melting and solidification of a solid-state substance (Ravanis, 2014). Moreover, Ravanis and Bagakis (1998) tried to change children's thoughts about the evaporation process, after inquiring about their misconceptions. In another study, Kampeza and Delserieys (2020) analyzed the drawings of young children aged four to seven years from a teaching intervention about melting. Kambouri-Danos et al. (2019) implemented a teaching intervention that aimed to support children aged from five to six years old to construct a precursor model about water state changes in eight phases. The children were asked to make predictions and offer explanations about the water state changes. The precursor models, according to Ravanis (2017) are placed between the original children's representations and the scientific ones and facilitate these thought processes that enhance children's thinking and connect it with scientific thinking.

It seems that even if children find difficulties with some notions about the water state changes and specifically of evaporation and condensation (Bar,1989; Kambouri-Danos et al., 2019) various teaching interventions can be used to be introduced to them at young ages such as dramatic activities (Åkerblom et al., 2019; Fragkiadaki & Ravanis, 2016; Karlsson, 2017) and experiments or predictions (Kambouri-Danos et al., 2019; Ravanis & Bagakis, 1998;). Although the previous research focused on water state changes individually some studies focus on the water cycle in nature. However, these studies focus mainly on cloud formation and rain (Ahi, 2017; Bar, 1986; Christidou & Hatzinikita, 2006; Malleus et al., 2017; Saçkes et al., 2010; Savva, 2014).

Research Questions

Considering the relevant literature and analyzing the relevant research, the following research questions, focused on the connection between new knowledge and everyday life situations-problems, emerge:

1. Could children link the ice with water?
2. Could children identify that ice is a form of water?
3. Could children understand why and how ice becomes water?
4. Could children solve real-life problems or other challenges using the new knowledge?

METHODOLOGY

The sample

This study involves a qualitative methodological approach. In the present study, a sample of fifteen (15) children aged 5 to 6 years old was conveniently selected and engaged in 4 main activities that took part in a Greek public Kindergarten in real classroom settings. The children that took part in this research had not previously attended any organized teaching activity on the water state changes. The present research is part of a STEAM project about water state changes and the Water Cycle in Nature. More specifically, phase 1 "Ice melting" is being presented.

The general plan of the process

The "Ice melting" phase has consisted of pre-tests, 4 main stages that follow the Engineering Design Process (EDP) for Early Childhood Education (Ioannou & Mourouzidou, 2021) and finally post-tests with the children. The preschoolers participate in the main activities and follow the 4 steps of the EDP (Figure 1): 1) Problem, 2) Inquiry, 3) Designing and Testing, and 4) Conclusions and Presentation.

The pre-tests were implemented a week before the main activities and the post-tests a week after the main activities. Both pre-tests and post-tests were individual semi-structured interviews between each preschooler and the researcher. The main theme of the interviews was the ice, preschoolers' ideas and experiences about ice, different contexts about ice, and one problem-solving situation.

The four stages of the Engineering Design Process (EDP)

The main activities were implemented according to the EDP in real classroom settings. The EDP was used to design and prepare the activities by the researcher/educator and also by preschoolers to follow certain steps to solve a specific problem. During the first stage (1.

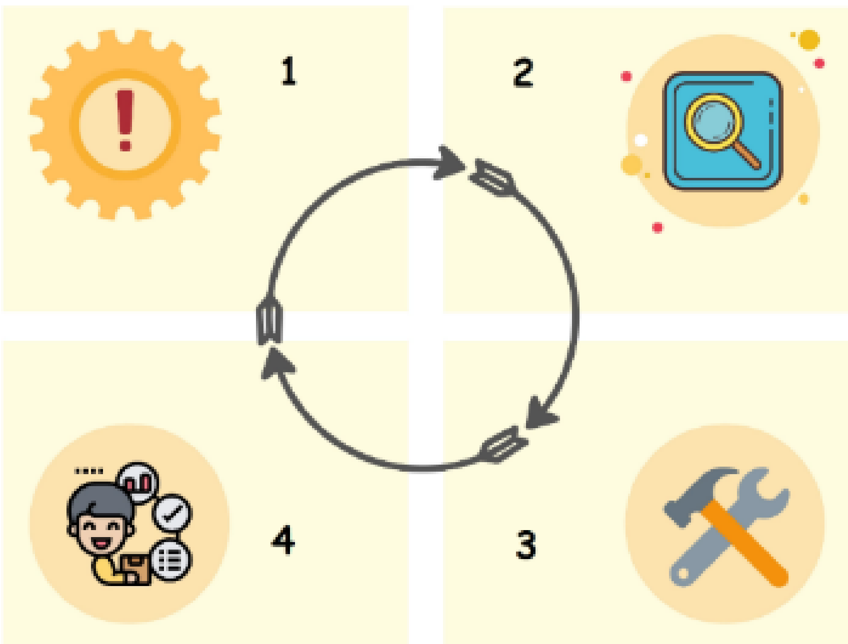
Problem) the researcher introduced a story about "a village on a high mountain where someone can find, during the winter, snow, and ice. The villagers face a problem with water because they cannot find water to wash their clothes, drink, and cook. They are forced to transport water from far away, which does not last for many days". In this stage, children are asked to identify the characteristics of the village, define the problem, and justify why this problem is important to be solved.

In the next stage (2. Inquiry) children are asked to express ideas for the specific problem and predict the possible results of their solutions. In this phase, it was crucial to discover connections between water and ice in children's ideas. During this activity, the researcher facilitated and encouraged the classroom discussion with all children and was responsible to record them on the interactive board.

In stage 3 (Designing and Testing) children were asked to design their solutions individually and justify their design choices. Subsequently, three experiments with ice were implemented at the same time by the researcher. Children observed and expressed their ideas while the experiments were implemented by the researcher for safety reasons. The three experiments were: a) heating ice cubes with a camp gas fire, b) ice cubes in a transparent lunch box, and c) ice cubes in a glass of water. Children, first, made predictions and then confirmed them at the end. Finally, in this stage, children in groups had the opportunity to play a music-motor activity called "solid-liquid" – "ice-water". Five children per group performed a dance and when they heard "Solid" or "Ice" they were freezing and hugged tightly while they heard "liquid" or "water" they moved with holding hands in a specific space.

In the final stage (4. Conclusions and Presentation) children were asked to present the final results and conclusions to another class of the schools or their parents. The researcher offered them plenty of materials (markers, brushes, colors, etc.) and asked them to emphasize HOW the village will find water, WHEN is possible to find water and WHY is this happening. Also, the researcher recorded their ideas in videos and voice clips. The outcomes were posted on a wall of the kindergarten.

FIGURE 1



The Engineering Design Process for Early Childhood Education

RESULTS

In this section, the results of phase 1 "ice melting" are going to be presented. First of all, the semi-structured interviews (pre-test) were encoded in 11 specific questions-categories and the answers were divided into two types of answers, sufficient answers that were closely related to preschoolers thinking about the ice and insufficient answers (Table 1).

In the first category, 11 out of 15 preschoolers tried to explain the nature of ice connecting ice with snow or describe it as "something cold". In addition, most of them connected the ice in nature with the ice cubes that are familiar with, and only a few connected the ice with water immediately. Four of the preschoolers provided insufficient descriptions or they did not provide descriptions at all. However, all of them stated that they have seen ice and the most common place was "in the North Pole", "in the village of Santa Claus" or "in the refrigerator" (category 2) and only 2 out of 15 could not answer where someone can find ice and when, while the 13 of them expressed the idea that "in winter" someone can find plenty of ice "on the mountains" (category 3).

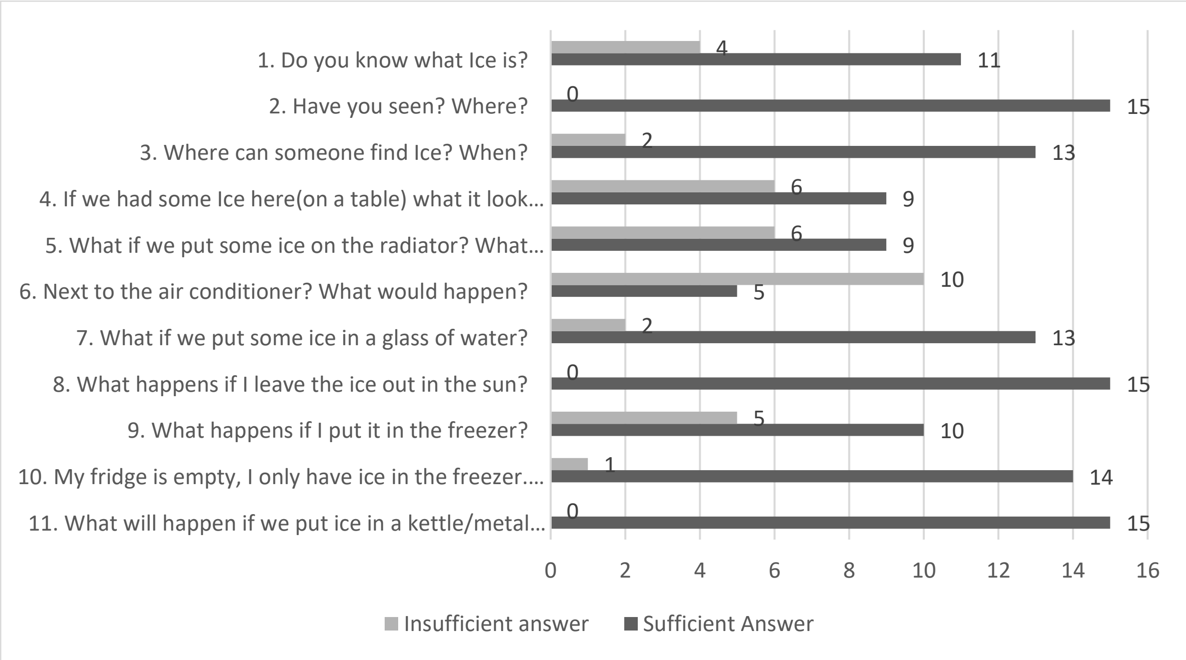
In the 4th category, children were asked to describe what some ice on a table would look like and what would happen if we put ice on a table. Most of them were able to describe the ice as "a triangle", "a circle" or "a square" that will melt a room temperature. However, 6 out of 15 stated that "the table will be frozen", or that "the ice will melt only if it is sunny, if it is not sunny it will remain cold". In the category of the ice on a radiator/heater, most of the preschoolers stated that the ice will melt but 6/15 stated that "the radiator will freeze" and that only the sun will cause ice melting. In contrast, 10 out of 15 children offered insufficient explanations on what would happen if we put some ice near an air conditioner and stated that the cold air of the air conditioner will keep cold the ice and prevent melting while only 2 out of 15 believe that if someone put some ice in a glass of cold water then the ice will remain cold and it will not melt. However, most preschoolers recognize that some ice in a glass of water will gradually melt.

All of the children recognized that if ice is directly pointed by the sun then it will melt because "the sun is hot", "the temperature of the sun is hot, not cold and the heat will melt it" and "the sun melts chocolates, jellies…" and in the same way the ice will melt. On the other hand, not all the preschoolers were able to offer sufficient answers regarding the ice in a refrigerator. 10 out of 15 stated that if someone put some ice in it then it will remain ice but 5 out of 15 stated that the ice will be increased, or they were not able to offer an answer. Moreover, 14 out of 15 children could solve a problem about an empty fridge that only has some ice in it, and if someone can drink water in some way. Most of the sufficient answers were about the sun and how we can use the heat of the sun to melt ice cubes.

Finally, in the last category of the pre-test, all the preschoolers predicted correctly that if we put ice in a kettle on top of a gas and set it on fire then the ice will melt and become water while 2 of them stated that some flames may come out first.

In the first stage of the main activities, the stage "Problem" children were introduced in a story that they should identify and justify the problem of the village while recognizing the special characteristics of it. In this stage video recording and personal notes of the researcher were analyzed. Children, firstly, recognized that the first image of the exclamation mark in a gear (Figure 1) is referring to a problem. Then, the researcher narrated the story about the village. This activity was implemented with all the children together. Children were able to identify the water problem of the village but also highlighted the characteristics of the village. During the discussion, they used their hands to represent the problem as they formed the mountain and the three aspects of the problem.

TABLE 1



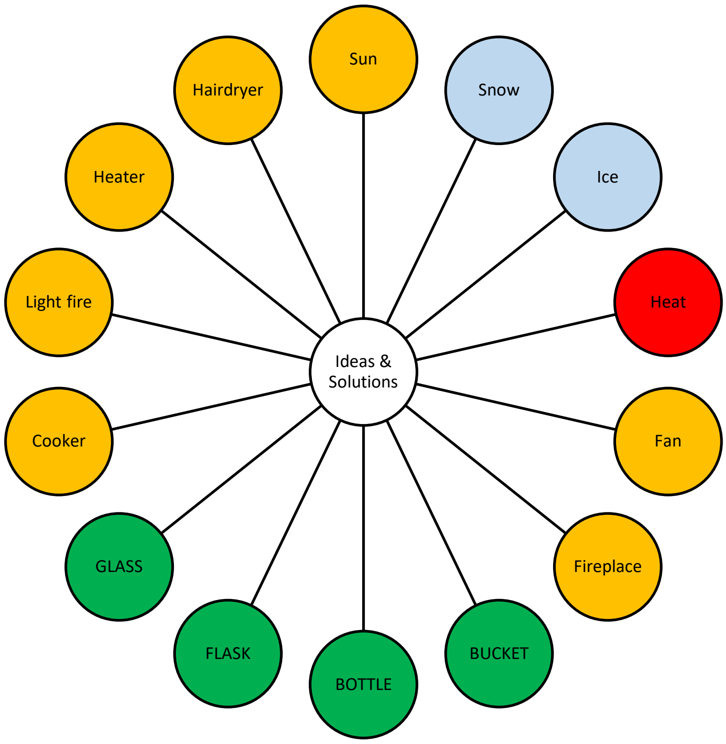
Pre-test semi-structured interviews

In the second stage, children were asked to express their ideas and their solutions to help the village overcome these problems. For this purpose, the researcher recorded their ideas on a concept map using an interactive board (Figure 2). Children highlighted the importance of heat (red) to melt the ice and the snow (light blue). They offered solutions based on their experience and gave some examples using the sunlight, a hairdryer, a fan, a fireplace, and other (yellow) "heating devices". Also, in this stage, children were introduced to the notions of solid and liquid states of matter following water state changes. All the children were actively engaged in the discussion. One preschooler stated that "heat… all of these that produce warmth, they have heat". Finally, they were asked to find ways to store water and they choose everyday products such as glasses, flasks, bottles, and buckets (green).

In the third stage, children were asked to draw their designs-solutions individually while they had the opportunity to discuss them in small groups (Figure 3). With the help of the researcher, the children present their designs in the class. Most of them decided to draw special glasses or buckets that will melt ice and store water made from glass, foam, or bricks. For example, at the bottom left one preschooler designed a special glass that holds an ice cube on top and while the sun melts it the water goes inside. Another preschooler drew an ice cube and rain that melts and a special bucket that concentrates the warmth of the sun and has a fireplace at the bottom to keep water in a liquid state of matter.

Then, the experiments (Figure 4) were implemented by the researcher in front of the children who were asked to make predictions and confirm or change them according to the final results. First, they made predictions for each experiment individually. Afterward, the ice was put on the camp gas fire in a small kettle, in a transparent lunch box, and a glass of water. Regarding the ice on the glass of water, 14 out of 15 children predicted correctly that the ice is going to melt while 2 out of 15 expressed the idea that the ice in the lunch box will remain ice. All the children predicted correctly that the ice in the kettle on the camp gas fire will melt because "it is hot, it has fire" and "it has heat". The three experiments were implemented at the same time and the children compared the time that passed in each case for ice to melt.

FIGURE 2



Concept map of children's ideas and solutions

FIGURE 3

Individual designing and small group discussion

The children confirmed that the ice on the camp gas fire melts faster than the ice in the glass of water. However, they realized that the ice in the lunch box was melting slowly. The children that predicted that the ice in this experiment will remain ice recognized then even at a slow pace the ice melts at room temperature. With the help of the researcher, children were asked to find a way to melt ice faster than in this situation. For this reason, children decided to transfer ice with their hands from child to child until it melts. After this race, they succeeded to melt ice faster than room temperature because of their "hot hands". They have also tested rubbing ice cubes to melt it faster. Thus, the children confirmed that the ice melted first on the camp gas fire, then in water, and then in the lunchbox. In comparison with the lunch box, they confirmed that they could melt it faster if they use their hands.

Finally, linked the solid with ice and liquid with water with a music motor activity (Figure 4) where children realized that ice is solid with strong structures (hugs) and water is liquid (hands holding) that takes the form of the available free space.

In the final phase of the main activities (4. Conclusions and Presentation) children were asked to find a way to make a presentation to another class and their parents about the problem they solved. After a long discussion, they decided to make a poster. Moreover, they were divided into presenters and cameramen to record their presentations (Figure 5). In this phase, children were able to answer HOW the village will find water, WHEN is possible to find water and WHY is this happening. The recordings revealed that children were able to justify their answers according to the previous activities and the outcomes of them. In addition, with the help of the researcher, QR codes were attached to the poster so other children and parents could easily scan and watch the children present their work and their presentations.

FIGURE 4

Experiments and ice-water activity

FIGURE 5

Conclusions and Presentation of the outcomes

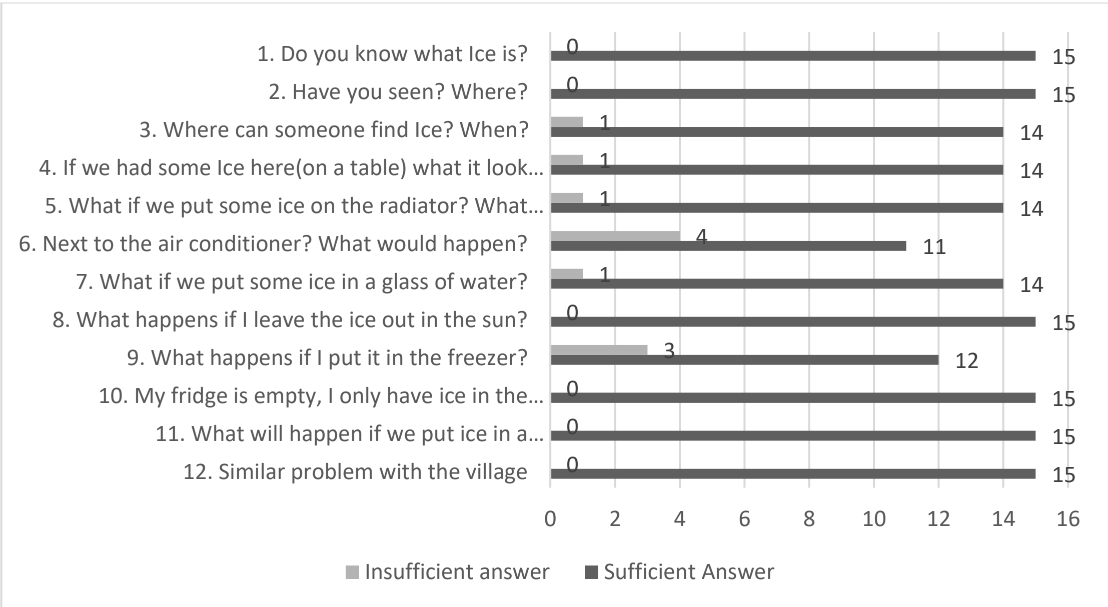
The post-tests (semi-structured interviews) were implemented a week after the final activity and encoded in 12 specific questions-categories and the answers were divided into two types of answers, sufficient answers that were closely related to preschoolers thinking about the ice and insufficient answers concerning the pre-tests (Table 2). The 11 categories were the same as the pre-tests and one final category was introduced where children were asked to solve a similar problem they solved in the activities.

In the first two categories, all of the children explained sufficiently the nature of the ice and directly linked it with the “cold water” and the ice cubes in the refrigerator. In the third category, only 1 preschooler was not able to justify where the ice can be found and when. In the fourth category, also, only 1 preschooler expressed the opinion that the ice will not melt on a table a room temperature because during the interview the preschooler touched the table and stated that "it will not melt because it melts when it is hot and in cold does not melt". Also, 1 preschooler stated that "if you put ice on the radiator and it is not powered on, then it will not melt" in the 5th category, however, all the other preschoolers predicted right.

There is an important difference in the category about the air conditioner between pre- and post-tests as 11 out of 15 believe that the ice will melt in this condition in contrast with the pre-test who were only 5. The 3 out of 15 believe that "if the air conditioner blows cold air, then the ice will not melt" while one preschooler stated that the air conditioner will freeze because of the ice next to it. In the category of the ice in a glass of water, most of the children predicted that the ice would melt while one preschooler stated that "in winter it cannot melt".

In the same ways as the pre-tests, post-tests revealed that all of the children recognized that if ice is directly pointed by the sun, then "the ice will become water". A slight difference is also observed regarding the ice in the freezer, with 3 out of 12 preschool answers remaining unchanged and stating that in the freezer "the ice can be increased". Finally, all the children were able to solve the case of the empty fridge, predict what will happen when we put ice in a kettle on the camp gas fire, and solve a problem similar to the problem that they already solved during the main activities.

TABLE 2



Post-test semi-structured interviews

CONCLUSION

Could children link the ice with water? The study findings indicate that the children who participated in this research were able to relate ice with water and describe ice as a state of water change. After the planned activities, the children were able to connect ice or snow with water. Especially important that after the activities all the children could describe ice and connect it to water using expressions such as "ice is frozen water" or "if the ice melts it becomes water".

Could children identify that ice is a form of water? According to the results of the main activities and the tests (pre-and post), it seems that the children could link the ice with water and identify that ice is a form of water. The answers to the post-test revealed that "cold water" is directly connected to ice cubes and that if an ice cube melts "it becomes water". All of the children were able to identify that ice is a form of water as they explained sufficiently the nature of the ice.

Could children understand why and how ice becomes water? Also, children seem to understand that heating is causing ice to melt and then it becomes water. The children recognize that a source of heating (e.g. camping gas, children's hands, the sun) or higher temperature in comparison with ice (e.g. room temperature, a glass of water) could cause the melting of the ice. Also, through the activities were able to understand why and how ice becomes water. this was established both from their expressions "heat… all of these that produce warmth, they have heat", the choice of heating sources for melting the ice (in the main activities) and from their answers in the post-tests where they recognized the ice-melting conditions.

Could children solve real-life problems or other challenges using the new knowledge? According to the findings, children were able to use the new knowledge to solve a real-life problem regarding the village and offer solutions to similar problems. During the main activities, children expressed ideas and predictions about a specific problem, they offered solutions and designs and through experimentation they presented the final outcomes that would help the village. Indeed, the solutions they offered concentrated on "how", "when", and "why" questions that helped the children understand the new knowledge and solve a real-life problem. Also, during the post-tests all the children were able to solve a similar problem to the one they already solved.

An interesting result was the significant change in the children's opinion about the air conditioner which, however, needs more analysis and investigation to be able to explain. A smaller change is observed in the relationship between the ice and the radiator. It is also important that during the post-test it took significantly different time for the children's answers with an average of about 3 minutes compared to the average of 5 minutes that each pre-test lasted.

In general, regarding the main activities, children were able to follow the 4 stages of the Engineering Design Process and the optical representation helped them remember the current step each time. During the first stage (1. Problem), the story about the village actively engaged children in the problem and offers them the opportunity to identify the problem and justify their ideas about the importance of solving the problem. Although a discussion between 15 children is often very difficult, with the support of the researcher, the discussion was successfully conducted.

During the second stage, children were asked to find solutions and express ideas about the problem and how they could solve this problem. All of them expressed at least one solution and the outcome was a concept map with 4 categories of ideas-solutions: 1) what is the "material" the villagers will have water from (light blue), 2) how the material will become water (red), 3) what products the villagers could help to melt ice and snow (yellow), and 4) where the villagers could store water (green). The Inquiry stage revealed children's ideas form their everyday life that could be used to melt ice and offer them the opportunity to discover the relation between ice and water.

In the third stage (3. Designing and Testing), children draw their solutions individually and offered ideas of where someone can store water or how can someone melt ice to drink water. Every child drew a solution such as glasses and buckets. Subsequently, children observed three experiments with ice cubes and made predictions. Most of them made accurate predictions and they had the opportunity to confirm the results of the experiments. Finally, they played a music-motor play where represented the ice (solid) and the water (liquid) with their bodies in small groups. It seemed that this stage was very important for the children because they had the opportunity to test their choices.

At the final stage (4. Conclusions and Presentation) children were asked to make a presentation about the outcomes of the activities and they created a poster with QR codes and video recordings. This stage revealed the final ideas of the children about ice melting as all of them were able to answer the three main questions: a) How the village will find water, b) When is possible to find water, and c) Why is this happening?

In this paper, a specific set of STEAM activities and the children's responses and results were presented. Although ice melting is something that most of the children are already familiarized and have some ideas, it was challenging to introduce a real-life problem through the Engineering Design Process and connect it to water state changes and specifically ice melting. This research used real classroom settings to introduce water state changes under the aspects of real-life problem solving to gradually introduce the water cycle in nature.

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