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# Representations of Children 5-6 Years Old about Electric Current: A Qualitative Approach

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**Abstract**— The present study aimed to investigate the mental representations of 5–6-year-old children about electric current. The research was qualitative in nature and was conducted using semi-directed individual interviews along three directions: An initial approach to children's mental representations regarding the presence of electric current in familiar environments, the place of its generation as well as the transport of it to houses. The findings showed that children tend to deal with the topic intuitively, mainly relying on their individual experiences. In addition, the findings revealed that despite the difficulties they face, young children have already formed some naïve mental representations about electric current. These results are part of a broader field of findings in the area of Early Childhood Education that studies the development of young children's thinking about natural phenomena and physical science concepts.

**Keywords:** Mental representations, electric current, 5–6-year-old children



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## 1. INTRODUCTION

The study of children's mental representations of natural phenomena and scientific concepts holds an important position in the Science Education context. In the literature, mental representations are often referred to as 'misconceptions', 'alternative ideas', 'preconceptions' etc. Regardless of what they are called, they count as entities which are formed in children's thinking in the natural and social environment, and which lead to reasoning different from that provided by school scientific knowledge (Weil-Barais, 1984). Therefore, the study of mental representations is important since they enable the design of specific teaching interventions aimed at leading children to forms of reasoning compatible with school scientific knowledge.

A small part of this research is carried out with children aged 3-8 years, developing over the last 30 years a diverse scientific field of research and application that is internationally recognized as Early Childhood Science Education (Hadzigeorgiou, 2015; Ravanis, 2022; Trundle & Saçkes, 2015). In this context, a number of studies have been carried out in thematic areas such as thermal phenomena (Kambouri-Danos et al. 2019; Pahl et al., 2022), astronomy (Hu et al., 2021; Jelinek, 2021; Raviv & Dadon, 2021), optical phenomena (Delserieys et al., 2017; Pantidos, et al., 2017), magnetism (Christidou et al., 2009; Kalogiannakis et al., 2018), biology (Ergazaki & Zogza, 2012; Villarroel et al., 2018), etc. A small part of these investigations was concerned with the mental representations of children 3-8 years old about electricity and elementary electrical phenomena.

In a particular limited number of studies, the researchers focused on the way young children deal with the concept of electricity and specifically electrical appliances. Along this line, Fleer (1991) illustrated that the differences between everyday and scientific language play a key role in the difficulties faced by 3–5-year-olds in

approaching electricity. In addition, Solomonidou and Kakana (2000) found that 6-year-old children can easily identify electrical devices which possess a functional entity that is stored inside them and has 'electricity' characteristics. Focusing on the understanding of household electrical appliances, Kalogiannakis and Lantzaki (2012) found that while the majority of 4-6-years-old children can satisfactorily associate them with electricity, a great number of them treat also other everyday appliances, that do not operate with electricity, as electrical. Furthermore, Kaliampos et al. (2020) found that only a few 5–6-year-old children have the capability to associate electricity with specific entities such as electrical appliances or properties such as lighting. On the other hand, quite interestingly Calo Mosquera et al. (2021) found that several 4–5-year-olds children associate electricity with appliances and induced electrical effects while having no particular difficulty in identifying electrical and electronic devices.

In a different research direction, a number of studies focused on the way young children deal with a simple electrical circuit made up of a battery, lamp, and wires. The results here shed light on specific difficulties as well as possibilities that children aged 4-8 years old exploit in connecting the battery with the lamp through wires. In particular, a study by Shipstone (1984) found that the battery was approached as an active source agent and the other elements as receivers, without being clear about what is produced and what ends up in the receivers. Two other studies with 5–6-year-old children came to a similar conclusion about the role of the battery. In the first one, children were asked to explain the autonomous movement of a toy car when the battery was placed in its specific position (Koliopoulos et al., 2009), while in the second they were asked to give explanations of the light bulb that shines in a simple electrical circuit (Kada & Ravanis, 2016). In another study that examined the way 5-6-year-old children engage with the construction of a simple electrical circuit, it was found that children have unstable approaches expressing a variety of opinions about the connections required in an electrical circuit, suggesting different types of explanations and possessing different levels of circuit construction skills (Glauert, 2009). The relationships between the predictions, choices and actions that children make with the circuit elements are not characterized by stability and balance, since, for example, children who make the same actions with the circuit materials make different predictions or give different explanations. Kalogiannakis and Lantzaki (2012) also showed that 4-6-year-old children have great difficulty in choosing the correct wiring of a simple electrical circuit when presented with alternative pictures. However, two other studies (Kada & Ravanis, 2016; Kaliampos et al., 2020) found that 5-6-year-old children have already begun to form satisfactory representations for connecting battery, bulb and wires to the operation of the bulb and that the majority of them are able, with or without assistance, to successfully construct such a simple electrical circuit. This finding is confirmed by similar studies into 3-5-year-old (Fleer, 1991) and 4-5-yearl old children respectively (Calo Mosquera et al., 2021).

In all of these studies, the concepts of electricity and electric current are often used without distinction as no emphasis is given on the distinction among static and moving electric charge due to the introductory and exploratory nature of the approaches. However, the, albeit rare, identification of an entity powering the light bulb in the simple electrical circuit, the electrical appliances or the battery-powered moving toys gives a first indication of the intuitive identification of a moving entity. Along this line, in the current research, an attempt was made to study young children's mental representations of the concept of electricity. The following three research questions were posed in the study:

a) What are children's mental representations of electric current?
b) Where is electricity located in various familiar environments?
c) Where is electricity generated and how does it come into our houses?

## 2. METHODS

### 2.1 Research Design

A qualitative approach was chosen since the aim of the research was exploratory due to the absence of relevant data in the international literature (Patton, 2002). The research was conducted through individual, directive structured interviews. Based on the transcriptions of the interviews a content analysis was carried out (Cohen et al., 2007).

### 2.2 Participants

The sample of the study consisted of 16 children aged 5-6 years old recruited from a public kindergarten class in an urban area of the city of Patras in Greece. All the subjects participated in the study on a volunteering basis as they were asked in advance whether they wished to talk to the researcher. In addition, the consent of their parents was sought while permission was obtained from the ethics committee of the Department of Educational Sciences and Early Childhood Education of the University of Patras. All levels of child performance (low, medium, and high) were represented in the convenience sample. It should be noted that none of the children had taken part in any organized activity related to electricity.

### 2.3 Procedures

Data were collected through semi-structured, individual interviews which were about 20 minutes long. Data analysis was carried out by two independent researchers based on the recorded and transcribed texts. During the interviews, protocols of nonverbal observations were followed by the second researcher. Children's transcribed responses to the researchers' questions were coded and classified into categories based on the research questions.

### 2.3 Research Instruments

The interview consisted of 12 questions divided into 3 distinct sections (see Appendix). Each section was corresponding to a research question. In particular, questions 1-4 were associated with the first research question, that of exploring children's mental representations of electric current. Questions 5-10 were associated with the second research question, that of exploring where could electricity be located in various familiar environments? Finally, the last two questions (11-12) related to the third research question, that of exploring where electricity is generated and how does it come into our houses.

### 2.3 Data Analysis

Analysis of the data collected from the interviews led to the classification of children's responses into three distinct levels: compatible with school knowledge, intermediate and insufficient. This analysis technique has been often used in similar

research on young children's mental representations and is based on estimating the distance between children's responses and the models used in school science knowledge.

## 3. RESULTS

### 3.1 First Research Question

The first research question aims to study how children approach electric current

#### *3.1.1 Questions 1, 2 & 3*

The first three questions aimed to study whether children had heard anything about electric current. If so, they fulfilled to clarify what was the source of their information as well as whether children were able to describe the concept of electric current. Children's responses were classified into three distinct categories.

3.1.1.1 In the category of responses compatible with school knowledge were classified those answers in which children were able to recognize the term 'electric current' while they could easily identify familiar sources of information, such as home, family or digital sources. In addition, they could associate electricity with elements of electrical circuits or electrical appliances. For example, Student 8: '*Yes (I know) … (I heard) from dad and mom… it's electricity… it goes through electrical wires… they are outside*'

3.1.1.2 In the category of intermediate responses were classified those answers in which while children tended to recognize the term of 'electric current' and made a clear reference to the source of information, they were not able to associate current with electricity-related objects. For example, S.6: '*Yes (I know) … (I heard it) when my dad had gone to work… no (I don't know what electricity is)*'.

3.1.1.3 Answers in which children did not recognize the term 'electric current' were classified in the category of insufficient responses.

Table 1 presents the frequencies of children's responses to questions 1-3.

**Table 1.** Frequencies of children's responses regarding the identification of electric current

| Responses | *N* | % |
|---|---|---|
| Sufficient | 3 | 18.75 |
| Intermediate | 8 | 50 |
| Insufficient | 5 | 31.25 |

#### *3.1.2 Question 4*

In the fourth question, children were asked to draw electric current, in an attempt to find out whether their drawings were related to electrical circuit elements or electrical appliances. Here data analysis led to three distinct categories of responses.

3.1.2.1 In the category of drawings compatible with school knowledge were classified as those that depicted electrical devices or elements of electrical circuits that refer to everyday devices or functions. For example, S.6 drew a television connected by a cable and socket where the electric current passes through the cable (Figure 1). Along this line, S.9 drew 3 electricity pillars equipped with a cable through which the current passes and goes '*to the Eiffel Tower making it light up as well as making the elevator work*' (Figure 2).

3.1.2.2 In the category of intermediate drawings were classified as those in which distinct and isolated electrical elements were designed. For example, S.10 drew a wire which was not related to any other source or element (Figure 3).

3.1.2.3 In the category of insufficient drawings were classified as those that did not depict anything related to electrical devices or circuit elements. For example, S.2 dew several blue dots clustered in one spot on the paper (Figure 4) while S.4 drew a radiator (Figure 5).

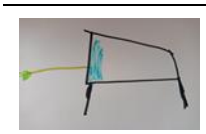
Figure 1


Figure 2


Figure 3


Figure 4


Figure 5

**Figures 1-5.** Children's drawings about electric current

Table 2 presents the frequencies of the children's drawings in question 4.

**Table 2.** Frequencies of children's responses regarding electric current

| Drawings | *N* | % |
|---|---|---|
| Sufficient | 7 | 43.75 |
| Intermediate | 4 | 25 |
| Insufficient | 5 | 31.25 |

### 3.2 Second Research Question

The second research question aims to record children's mental representations regarding the presence of electric current in familiar environments such as electrical appliances and devices.

#### *3.2.1 Questions 5 & 6*

With these questions, an attempt was made to record the familiar objects and functions that children tend to associate with the term of 'electric current'. Children's responses were classified into three distinct categories.

3.2.1.1 In the category of responses compatible with school knowledge were classified those answers in which children referred to specific appliances and devices that operate with electric current. For example, S. 4 indicated stove, water heater, and radiator: '*Yes, it has some tubes that runs on current*'. Along this line S. 6 indicated 'the power plant' and stated that '… *electricity helps things work well and supply the power to make people be warm and see what they want*'.

3.2.1.2 In the category of intermediate responses were classified those answers in which children's references were either vague (for example S.11. '*At home*') or included clarifications that had nothing to do with electrical phenomena. For example, S.8. stated '*In the refrigerator … When something is too hot or too cold … if the fridge is cold enough I know that there is electricity inside*'.

3.2.1.3 Answers in which children stated '*I don't Know*' or did not express any thought at all were classified as insufficient responses.

Table 3 presents the frequencies of children's responses to questions 5 and 6.

**Table 3.** Frequencies of children's responses regarding the identification of familiar objects and functions based on electric current

| Responses | *N* | % |
|---|---|---|
| Sufficient | 6 | 37.5 |
| Intermediate | 6 | 37.5 |
| Insufficient | 4 | 25 |

### *3.2.2 Question 7*

Here the children were asked to identify which objects 'have electric current' by showing them a series of three sets of cards depicting objects in the living room and kitchen, electricity-related and non-related objects as well as electrical appliances on and off. In most cases, children's responses were satisfactory, although it was found that children sometimes tend to consider that electrical appliances that are out of order have a current that could not be seen. Their responses were classified into three distinct categories.

3.2.2.1 In the category of responses compatible with school knowledge were classified those answers in which children responded satisfactorily with the items of all three groups of cards regarding the identification of electric current. For example, S.5 having correctly choose the items related to electricity, he distinguished which appliances were on and off: '*TV that is turned off has no electricity … the TV that is on has electricity*'.

3.2.2.2 In the category of intermediate responses were classified as those answers in which children's statements were characterized by variations or doubts regarding the operation of electrical appliances.

3.2.2.3 Answers that were mainly characterized by uncertainty or contradictions were classified in the category of insufficient responses.

Table 4 presents the frequencies of children's responses to question 7

**Table 4.** Frequencies of children's responses regarding the identification of objects that operate with electricity

| Responses | *N* | % |
|---|---|---|
| Sufficient | 10 | 62.5 |
| Intermediate | 4 | 25 |
| Insufficient | 2 | 12.5 |

### *3.2.3 Questions 8 & 9*

In questions 8 and 9 an attempt was made to detect whether children were able to identify electricity in appliances that were placed in the classroom and consider the same for appliances that are present in their home. Their responses were classified into two categories.

3.2.3.1 In the category of responses compatible with school knowledge were classified those answers in which children responded satisfactorily as they selected, without hesitation, appliances that were operated with electric current in the classroom and their homes.

3.2.3.2 In the category of intermediate responses were classified those answers in which children's statements regarding question 8 were mainly characterized by inconsistencies, as they pointed out that electric current was apparent in appliances that

were out of order. While they often tented to undone their choices during the interview, it was clear that these choices had a repetitive form.

Table 5 presents the frequencies of children's responses to questions 8 & 9.

**Table 5.** Frequencies of children's responses regarding the identification of electric current in familiar surroundings

| Responses | *N* | % |
|---|---|---|
| Sufficient | 6 | 37.5 |
| Intermediate | 10 | 62.5 |

### *3.2.4 Question 10*

In question 10 an attempt was made to record whether children were able to detect electricity in their wider environment, i.e. beyond their familiar surroundings. Their responses were classified into two distinct categories.

3.2.4.1 In the category of responses compatible with school knowledge were classified those answers in which children responded satisfactorily as they tended to detect electrical devices that operate in the wider environment. For example, S.10 pointed out: '*On the tall pillars that have electric current … on the car's front and back lights … it has batteries, no wire that comes along where it goes*'.

3.2.4.2 In the category of intermediate responses were classified as those answers that were either incomplete or characterized by severe inconsistencies. For example, S.9 stated: '*In the electricity cables … in the wheels of cars …'*.

Table 6 presents the frequencies of children's responses to question 10

**Table 6.** Frequencies of children's responses regarding the detection of electric current in the wider environment

| Responses | *N* | % |
|---|---|---|
| Sufficient | 6 | 37.5 |
| Intermediate | 10 | 62.5 |

## 3.3 Third research question

The third research question aims to study children's mental representations of the place of electric current generation and the transport of it to houses.

### *3.3.1 Question 11*

In question 11 an attempt was made to study children's representations about the place of electrical generation. Their responses were classified into three distinct categories.

3.3.1.1 In the category of responses compatible with school knowledge were classified those answers in which children identified a specific place of electrical generation '*at the electrical factory*' (S.4) or '*at the power plant*' (S.6).

3.3.1.2 In the category of intermediate responses were classified as those answers in which the existence of a specific area is acknowledged, even though there is some confusion about its nature. For example, S.5: *'In a building that breaks sockets and turns them into electricity*', S10: *'In a rubbish factory'*.

3.3.1.3 In the category of insufficient responses were classified as those that were not characterized by any specific place. Instead, specific appliances were mentioned such as S3: '*At the socket*', S11: '*At the lights … at the stoves … at the TV'*.

Table 7 presents the frequencies of children's responses to question 11

**Table 7.** Frequencies of children's responses regarding the place of electric current generation

| Responses | *N* | % |
|---|---|---|
| Sufficient | 3 | 18.75 |
| Intermediate | 4 | 25 |
| Insufficient | 11 | 68.75 |

### *3.3.2 Question 12*

In the last question, an attempt was made to capture the possibility of the children identifying the movement of the current on a broad scale, despite the fact that the phrase 'plan the journey' may bias their ideas. Here data analysis of children's plans led to three distinct categories of responses.

3.3.2.1 In the category of responses compatible with school knowledge were classified those answers in which a generation point, transmission cables, and a consumption point were clearly depicted. For example, S.3 drew a very simple drawing with two buildings connected through a cable (Figure 6) while S.11 drew a factory, a house, pillars as well as connecting cables (Figure 7).

3.3.2.2 In the category of intermediate responses were classified those answers in which the idea of transfer was present but either the drawings were characterized by specific shortcomings or the explanations accompanying the drawings were weak. For example, S.6 considered the transfer from the factory to the house as follows: '*It is a factory that constructs the electricity … a man picks it up with a special tool … he puts it on an electric trolley and carries it to the house …*' (Figure 8). In addition, S.9 drew a TV (Figure 9) and pointed out: '*The electricity comes through the electrical pillars'*.

3.3.2.3 In the category of insufficient responses were classified those drawings that had a high degree of ambiguity despite the useful information they might contain. For example, S.7 drew a vague green outline as representing the 'factory' and the 'current' without providing any connection among them (Figure 10).

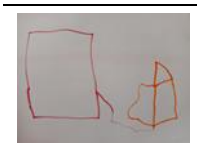
Figure 6


Figure 7


Figure 8

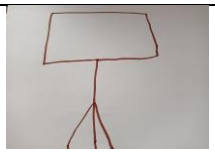
Figure 9


Figure 10

**Figures 6-10.** Children's drawings about the transportation of electric current

Table 8 presents the frequencies of children's drawings regarding question 11

**Table 8.** Frequencies of children's drawings regarding the movement of electric current

| Drawings | *N* | % |
|---|---|---|
| Sufficient | 7 | 43.75 |
| Intermediate | 3 | 18.75 |
| Insufficient | 6 | 37.5 |

## 4. DISCUSSION

In the current research, an attempt was made to record qualitatively and multilaterally the mental representations of 5-6 years old children about electricity. Our results are broadly consistent with the findings of international literature. In particular, they highlight on the one hand the limitations of pre-logical thinking (Laurandeau & Pinard, 1972) that seems to be prevalent at this age and on the other hand they feature new aspects of Science knowledge construction that seems to be possible from early childhood (Boilevin et al., 2022).

The first research question attempted to record children's representations of the term 'electric current'. A small number of children seem to be able to use this term appropriately in an everyday context. These children associate 'electric current' with electrical appliances and are capable of depicting them in drawings that illustrate connections with wires, sockets, etc. However, the majority of children cannot conceptualize the term as they either refer to it in a fragmentary and unstable way or do not have formed any kind of relevant representation about it.

The second research question attempted to focus the discussion on the presence of electric current in familiar environments. Here several children could successfully refer to everyday electrical appliances or wires outside their houses and even more successfully distinguish pictures of electrical appliances from non-electrical ones. As found in the relevant literature, it seems that young children are able to better conceptualize electrical phenomena as soon as these phenomena are placed in a familiar context (Calo Mosquera et al. 2021; Kaliampos et al., 2020; Kalogiannakis & Lantzaki, 2012).

The third research question seeks to study children's mental representations of a broader context, that of the place of electric current generation and the transport of it to houses. The results seem to be better when the children are asked to draw the 'journey' that electric current takes to get to houses, even though this formulation is likely to bias their ideas through the construction of certain mental representations through the interview process. The possibility of constructing representations using the concept of 'journey' has been frequently found with 5–6-year-old children in relation to propagating energy entities such as light (Ravanis et al., 2013) or sound (Ravanis et al., 2021). These findings are consistent with the relevant literature in which an electric moving entity is identified Solomonidou & Kakana (2000).

Despite the limitation of the small sample of the study, the results clearly show that while young children's mental representations of electricity are far from school scientific knowledge, the children themselves are already on a path of cognitive processing of satisfactory mental representations.

## 5. CONCLUSION

The findings of the present research are fully consistent with those that lie on the broader context of Early Childhood Science Education. In particular, it was found that

5–6-year-old children are able to approach aspects of the concept of 'electric current'. Undoubtedly, their approach is intuitive and closely linked to personal experiences that arise from their familiar environments. However, despite the fragmentary way in which they deal with electric current, it is apparent that they have already formed in their minds the initial naïve mental representations which can form a strong basis for the development of teaching activities aimed at constructing new representations compatible with school scientific knowledge (Ravanis et al., 2022).

These findings are also of great interest for primary education and teacher training since the organization of specialized teaching situations requires specific knowledge related to the difficulties faced by young children (Ergazaki & Ampatzidis, 2016; Kornelaki & Plakitsi, 2018; Li et al., 2022; Paskou et al., 2022).

The qualitative nature of the research allowed for a detailed approach to children's thinking who participated in the sample, which however was very limited. Undoubtedly, a quantitative survey with representative samples which could extend to environments with diverse cultural characteristics would have given a new dynamic and breadth to the results of the study.

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## APPENDIX

### Interview Questions

1. Have you ever heard the phrase 'electric current'?
2. Where did you hear about it? Do you remember what they said about it?
3. Do you know what it is?
4. Can you draw how you imagine electric current?
5. Do you know where electric current can be found?
6. How can I understand whether an object has electric current?
7. Figures
    - Living room/kitchen: Can you identify where there may be electric current?

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2023, Vol. 2, No. 1, 1-14

- Electrical Devices/Objects: Which of them operates with electric current?

- In operation/ Out of operation: Which one operates with electric current?

8. Is there any electric current here (in the room)? How do you know it? In which places electric current is located?

9. Is there electric current in your house? In which parts of it can be found?

10. Can we find electric current outside the house, i.e. in the street or in the square?

11. Where is electric current generated?

12. Can you draw the journey that electric current takes to reach our house? From which place does electric current depart and how does it get to the house?

13. The electric current in its departure place is the same or different with the one that comes into our school and houses? Why?

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