VISUALIZATIONS IN PRIMARY EDUCATION. EFFECTS ON THE CONCEPTUAL UNDERSTANDING OF BASIC ASTRONOMY CONCEPTS FOR CHILDREN UP TO TEN YEARS OLD

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Abstract

The purpose of this study was to identify which types of visualizations (i.e., sketches/non-realistic pictures, cartoon-like animations, realistic photos, realistic videos and holograms) are more conducive to the conceptual understanding of children up to ten years old. Specifically, we investigated how static (i.e., sketches/pictures, realistic photos) and moving (i.e., cartoon-like animations, realistic videos, holograms) visualizations compare, as well as how realistic (i.e., photos, videos, holograms) and non-realistic (i.e., sketches/non-realistic pictures, cartoon-like animations) visualizations compare.

The sample of this research consisted of 150 children (75 kindergarteners between five and six years old and 75 fourth-graders aged up to ten years old). Each age group was divided in five conditions based on the type of visualizations used (15 students per condition). Semi-structured interviews and constructed learning objects/artifacts (e.g., models) were used as the main data resources for this mixed methods study. The interview and the creation of the learning artifacts, focused on basic astronomy concepts, namely the shape of the sun and the earth, the earth movements and what causes day and night. Results revealed that moving visualizations (i.e., cartoon-like animations, holograms and realistic videos) are the most effective in facilitating student learning, whereas realism does not appear to be a requirement for enhancing students’ understanding, since cartoon-like animations were found to be effective in facilitating learning among the participants of our study.

Keywords: Visualizations, videos, animations, pictures, holograms, early science education.

1 INTRODUCTION

Visualizations could offer valuable information on how the world works to learners across all ages [1, 2, 3]. Additionally, Visualizations have proven to be effective teaching and learning tools in science education [3]. For instance, visualizations can transform invisible scientific processes (e.g., processes at a molecular level) into visible processes, or transform abstract concepts (e.g., vectors) into concrete ones (e.g., arrows are used to represent vectors). By integrating them in science education, teaching becomes more interesting, more accessible to children, and gives the opportunity to students to discover, experiment, analyze and visualize physical phenomena across the natural sciences [1]. Furthermore, the integration of visualizations can assist students to develop a range of skills, such as scientific skills (e.g., design an experiment), thinking skills (e.g., problem solving), practical skills (e.g., use of materials and equipment), and spatial skills [2], as well as to develop better understanding of the physical phenomena occurring all around us.

The need to create and use visualizations can be traced back to the early days of mankind, when our ancestors’ attempted to create images, in order to encode cognitive representations, primarily, for communication purposes. Science teachers and researchers have emphasized that, visualizations are particularly useful for science teaching and learning due to the information and communication power they inherently carry. The latter transforms them into vital tools for facilitating learning across the sciences. In 2014, Ainsworth and Newton [3], conducted a literature review in which they studied 401 scientific articles focusing on visual representations (i.e., visualizations). They argued that, there are various types of visualizations (e.g., sketches/pictures, cartoon-like animations, realistic photos, realistic videos/animations and holograms), which in turn are separated in static (e.g., sketches/pictures, realistic photos) and moving (e.g., cartoon-like animations, realistic videos and holograms) visualizations, that can be used across all domains and at all levels of science education.

The purpose of the current study, was to identify the more effective types of visualizations, with regards to the conceptual understanding of young children. In so doing, the research focused on students’ level of understanding (i.e., by measuring their performance on content-oriented questions), while exposing children to different types of visualizations: sketches/non-realistic pictures, cartoon-like
animations, realistic photos, realistic videos and holograms (3D representations; see Figure 1).
Specifically, our study aimed at answering the following questions:

1. Does the use of moving (i.e., cartoon-like animations, realistic videos, holograms) and static
(i.e., sketches/non-realistic pictures, realistic photos) visualizations have a different effect on
kindergarteners’ and fourth-graders’ understanding of astronomy concepts?

2. Does the use of realistic (i.e., photos, videos, holograms) and non-realistic (i.e.,
sketches/pictures, cartoon-like animations) visualizations have a different effect on
kindergarteners’ and fourth-graders’ understanding of astronomy concepts?

2 METHODOLOGY
This study was conducted in public schools in Cyprus. The sample of the study consisted of 150
children (75 kindergarteners and 75 fourth-graders), who were separated into five conditions per age
group. In particular, each age group was divided in five groups of 15 students, based on the type of
visualizations used (see Table 1).

<table>
<thead>
<tr>
<th>Visualizations</th>
<th>Visualizations</th>
</tr>
</thead>
<tbody>
<tr>
<td>(no. of kindergarteners)</td>
<td>(no. of fourth-graders)</td>
</tr>
<tr>
<td>Sketches/non-realistic pictures (15 students)</td>
<td>Sketches/non-realistic pictures (15 students)</td>
</tr>
<tr>
<td>Cartoon-like animations (15 students)</td>
<td>Cartoon-like animations (15 students)</td>
</tr>
<tr>
<td>Realistic photos (15 students)</td>
<td>Realistic photos (15 students)</td>
</tr>
<tr>
<td>Realistic videos (15 students)</td>
<td>Realistic videos (15 students)</td>
</tr>
<tr>
<td>Realistic holograms (15 students)</td>
<td>Realistic holograms (15 students)</td>
</tr>
<tr>
<td>Total 75 kindergarteners</td>
<td>75 fourth-graders</td>
</tr>
</tbody>
</table>

Semi-structured interviews and constructed learning objects/artifacts (e.g., models) were used as the
main data resources for this mixed methods study. The interview protocol consisted of two parts. The
first part followed the Predict-Observe-Explain strategy [4] and involved the use of the visualization
tool of the condition. The second part focused on comparing the visualization used in the first part of
the interview with a hologram, after all students experienced the use of holograms. In particular, after
the completion of the aforementioned data collection, all the students, but the students of the hologram condition, were presented with a hologram. Right after, a new interview was enacted. The aim of this second interview was to encourage students to express their views on this new visualization tool and compare it with the one used before. The children who participated in the hologram group, were presented with realistic videos.

The structure and evolving process of the interviews was the same for all conditions and lasted about the same time. Additionally, during the enactment of the interview protocol, all students were asked to make predictions and explain their reasoning (think-aloud-protocol). For the creation of learning products/artifacts the same set of materials (e.g., plasticine clay) was provided per condition, before, during and after the interview.

Each visualization of each condition involved both acoustic and visual input. The visual input varied according to the visualization representation used per condition. The acoustic input was exactly the same for all five conditions.

The interview and the creation of the learning artifacts, focused on basic astronomy concepts, namely the shape of the sun and the earth, the earth movements and what causes day and night. We have selected basic astronomy concepts as the subject domain of our study because they are highly related to everyday life experiences. None of the students had an earlier formal teaching on these concepts.

The data analyses followed both qualitative (e.g., open coding and classification of students ideas on the concepts at task) and quantitative (i.e., use of statistical tests) procedures. For the purposes of this study, we included data analysed both quantitatively and qualitatively. The qualitative methods used, followed, initially, open-coding and then the Grounded Theory method. For the quantitative data analyses we used non-parametric tests (e.g., Kruskal-Wallis, Mann-Whitney and Wilcoxon) for both within and between condition comparisons.

For measuring students’ conceptual understanding we used data collected both through the interview and the artefacts constructed by the students. The scoring of these data involved rubric tables. A total score per student was calculated and used in the quantitative data. Inter-rater reliability data were collected and calculated. Cohen’s kappa was found to be greater than 0.86 across all analyses.

3 RESULTS

Overall, our results showed that the use of moving visualizations (i.e., cartoon-like, holograms and realistic videos) are more conducive to the learning of the students of both ages, as opposed to the static visualizations. Static sketches/non-realistic pictures were found to have the least effect on students’ learning. These findings appear to point towards a particular direction in terms of the type of visualizations that should be used in early science education. Right below, we provide more detailed results concerning students’ conceptual understanding in conjunction with the visualizations used.

3.1 Conceptual Understanding

3.1.1 The shape of Earth and Sun

Regarding the shape of the earth and the sun, almost none of the kindergarteners and few of the fourth-grade students were able to name and create the sphere shape prior to the first part of the interview. The kindergarteners’ and the fourth-graders’ carrying all sort of misconceptions concerning the shape of the earth and the sun, characterized the shape of the earth and the sun as circular, round or, even, cylindrical, and as a result created models of 2-D in nature (see Figures 2 and 3) before experiencing their visualizations. Right after experiencing their visualizations only the kindergarteners and the fourth-graders of the moving visualization conditions (i.e., cartoon-like, holograms and realistic videos) managed to create spherical 3-D models of the earth and sun. The kindergarteners and the fourth-graders of the moving visualization conditions (i.e., cartoon-like, holograms and realistic videos) managed to create spherical 3-D models of the earth and sun. The kindergarteners and the fourth-graders of the sketches/non-realistic pictures and realistic photos conditions, who initially created models of 2-D in nature, created similar, 2-D in nature, models after experiencing their visualizations. Needless to say, the absence of experience of the 3-D nature of the earth and the sun restricted the kindergarteners and the fourth-graders from creating 3-D models.

The realism factor was not found to affect students’ understanding of this particular topic. For instance, the cartoon-like animations were to have the same effect as the holograms on kindergarteners’ and the fourth-graders’ understanding of this particular topic.
3.1.2 Earth movement and what causes day and night

Kindergarteners’ and the fourth-graders’ views on how the earth moves and what causes day and night varied before using the visualization tool of their condition. Many fourth-graders attributed the day shifting into night, to the rotation of the earth around the sun, rather to its rotations around its axis. Some other fourth-graders attributed the day shifting into night to the rotation of the sun around the earth. Very few fourth-graders were able to describe how the earth rotates around its axis and orbits around the sun.

The kindergartens had a more distorted view of the phenomena. First, almost none of them had the view that earth moves around the sun. The majority of the kindergarteners argued that the earth is still. As for what causes day and night, the kindergarteners explained that it is due to sun’s hiding, or sun’s will to leave to go somewhere else, or sun’s willingness to go to sleep.

After the kindergarteners’ and the fourth-graders’ exposure to the visualization of their condition, the majority of the fourth-graders, especially the ones who experienced moving visualizations (i.e., cartoon-like, holograms and realistic videos), were in a position to attribute the shift to the rotation of the earth around its axis and that the earth orbits around the sun. Surprisingly, the moving visualizations had an effect only on part of the kindergarten students. Apparently, the strong nature of their misconceptions prevented them from understanding the phenomenon.

The realism factor was also not found to affect students’ understanding of this particular topic.

4 CONCLUSIONS

The general conclusion emerging out of this study is that the use of visualizations is beneficial for students’ learning, especially the moving ones. The most effective visualizations appear to be the moving ones that are three-dimensional (i.e., holograms) or have the visual feeling of 3-D (i.e., videos, cartoon-like animations), because they offer clearer representations of the represented concepts and phenomena [5, 6]. Interestingly, these findings apply both to kindergarteners and the fourth-graders, which means that similar visualizations could be used when teaching science at these different age groups. Therefore, moving visualizations should be preferred over static ones both at the kindergarten and the fourth grade level.

Another interesting finding of this study is that the degree of realism of the visualizations does not appear to affect kindergarteners’ and fourth-graders’ learning, at least for the topics included in this study. The latter implies that both realistic and non-realistic (e.g., animated) visualizations could affect kindergarteners’ and fourth-graders’ understanding in a similar manner. The only prerequisite, based on our previous finding, would be that the visualizations are moving in nature.
REFERENCES


