

A CASE STUDY OF CYPRIOT PRIMARY SCHOOL STUDENTS' USE OF A DYNAMIC STATISTICS SOFTWARE PACKAGE FOR ANALYZING AND INTERPRETING DATA

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The use of dynamic learning environments, which are designed explicitly to facilitate the visualization of mathematical concepts, provides an enormous potential for making complicated mathematical ideas accessible to young learners. This paper explores the potential of dynamic statistics software for supporting the teaching and learning of probabilities. It shares the experiences from a case study that implemented a data-driven approach to mathematics instruction using the dynamic data-visualization software InspireData[®], an educational package specifically designed to meet the learning needs of students in the middle and high school grades (Grades 4-12). We report on how a group of Grade 4 (about 9-year-old) students used the affordances provided by the dynamic learning environment to gather, analyze, and interpret data, and to draw data-based conclusions and inferences. The role of the technological tool in scaffolding and extending these young students' stochastic and mathematical reasoning is discussed.

LITERATURE REVIEW

There is ample research evidence (e.g. Franklin et al., 2007; Gil & Ben-Zvi, 2011; Hall, 2011; Ireland & Watson, 2009; Konold & Lehrer, 2008; Paparistodemou & Meletiou-Mavrotheris, 2008) that the use of dynamic statistics software promotes the development of important data literacy and analytical skills, and of more coherent mental models of core mathematical concepts (e.g., theoretical probability, experimental probability, relative frequency, percent, fraction, measures of center and spread, algebraic relationships, line of best fit). These technological tools are designed to explicitly facilitate the visualization of mathematical concepts by offering a learning environment that allows the construction and flexible usage of multiple representations of mathematical ideas. All objects of dynamic software are continuously connected and, thus changes in one representation are automatically reflected in all related representations. This dynamic nature provides a medium for the design of activities that integrate experiential and formal pieces of knowledge, allowing the user to make direct connections between physical experience and its formal representations (Meletiou-Mavrotheris, 2003; Paparistodemou, Noss, & Pratt, 2008).

The design of dynamic statistics software packages (e.g., Tinkerplots[®], InspireData[®]) drew on current constructivist theories of learning as well substantive academic research about the way students at school level learn and process statistical concepts and the main difficulties they face (Biehler, Ben-Zvi, Bakker, & Makar, 2013). Dynamic statistics software have been designed “from the bottom up”, building on the foundation of what learners already understand (Konold, 2010). They can do much more than producing fancy graphs. They could, through a data-driven perspective, help students internalize key mathematical concepts across the school curriculum while at the same time developing data literacy skills. Their integration into the mathematics curriculum can bring data analysis into the classroom in meaningful, relevant and accessible ways that could help convince students of the usefulness of mathematics.

Dynamic statistics software packages go far beyond the role of mere means for data display and visualization to become a tool for thinking and problem solving. Students can experiment with statistical and mathematical ideas, articulate their informal theories, use the theories to make conjectures, and then use the experimental results to test and modify these conjectures. This leads to a shift in the focus from learning statistical tools and procedures (e.g., graphical representations, numerical measures) towards more holistic, process-oriented approaches. Statistics can be presented as an investigative problem-solving process that involves formulating questions, collecting data, analyzing data, and drawing data-based conclusions and inferences (Franklin et al., 2007).

METHODOLOGY

This small scale project was a teaching experiment that took place in a fourth-grade mathematics classroom in a rural primary school in Cyprus, during the Spring 2013 semester. Fourteen Grade 4 students (about 9 years old) participated in this research project. The research took place over a period of three weeks. There was one meeting per week in the school computer suite and each meeting lasted about 80 minutes. Students completed a pre-experimental questionnaire before interacting with the software and a post-experimental questionnaire on probabilities.

A core element of the teaching experiment was the functional integration of technology with existing core curricular ideas, and specifically, the integration of the dynamic statistics software InspireData[®] (Hancock, 2006), an educational package specifically designed to meet the learning needs of students in the middle and high school grades (Grades 4-12). Working collaboratively, children employed the features of InspireData[®] to collect, analyse, and explore data, and to formulate and evaluate conjectures based on the data they had collected.

The first author carried out the teaching experiment in the school's computer suite as a teacher-researcher. Students conducted a class survey to collect information about themselves (gender, hair colour, eye colour, number of siblings, number of pets), entered the data into InspireData[®], and used the software to analyse and interpret the data. During the last class in the computer cluster students filled in a post-experimental questionnaire on probabilities. Based on Venn diagrams of collected data, children wrote probabilities in fraction and percent form to answer questions such as the following:

If all student names in our class were put into a hat and one was pulled out at random, what is the probability that the student: has brown eyes? has at least one sibling and at least one pet? is female and has black hair? has brown eyes, black hair and less than 4 siblings?

A variety of qualitative data gathering techniques were employed in order to assess students' learning and motivation as a result of interacting with the dynamic software: researchers' observations, informal interviews of selected students (the interviewing took place while students were working in pairs on analyzing their data), and students' work samples. The study sought to identify and understand students' interactions with the dynamic statistics software, and the ways in which these interactions influenced their statistical reasoning. The method of analysis involved inductively deriving the descriptions and explanations of how students interacted with the software, and approached selected ideas of mathematics and statistics. The descriptions derived formed the study's findings that are outlined in the next section.

FINDINGS

Students were asked to analyze the data using Venn diagrams and they were able to see how each case study student (represented by a picture) belonged to a Venn diagram according to a certain criterion. For example, students could see how boys and girls having brown eyes belonged to the same Venn diagram, of children with brown eyes. When the criteria changed for each Venn diagram the pictures moved dynamically on the students' computer screen to match the criterion given. Thus, in Figure 1, students could see two cases of boys that were left outside the Venn diagrams because they had neither brown hair, nor brown eyes, and their number of siblings was not 2 either (it could be more or less). These Venn diagrams, a unique tool offered by InspireData[®], helped the students to visualize the data and to respond to some questions on probabilities they were given on a handout. With prompting from the teacher-researcher, the children also attempted to draw informal inferences "beyond the data at hand" (e.g., probability of children in the whole school having at least one sibling and at least one pet, probability that a Cypriot child has blue eyes and how this compares with the probability that a child from Sweden has blue eyes). Table 1 summarizes students' responses on some probability questions.

As shown in Table 1, all students answered correctly questions 1, 2, 3, 9 and 10. The wording of questions 1 and 2 was short and the students had only one criterion in mind so it was easier to find the answer in the dataset. Question 3 was also easy to spot in the dataset because everybody in the classroom had at least one sibling and at least one pet. Question 9 was referring to a single case of a blonde male student with black eyes, which stands out from the dataset, thus the

students responded correctly. The same goes for question 10: nobody in the classroom had more than 4 pets, no siblings and brown hair, so the students found the answer 0 perhaps just by looking at the first criterion (i.e. more than 4 pets) while ignoring the other two (i.e. no siblings and brown hair).

Apparently, the most difficult question for students was question 11. Nobody could answer this question correctly and we interpret that to be a result of the wording of the item. The phrase ‘no more than 2 pets’ implies three different scenarios: 0 pets, 1 pet or 2 pets and perhaps this was confusing for the students. Moreover, this question had another criterion ‘no more than 2 siblings’, which again refers to three different scenarios: 0 siblings, 1 sibling or 2 siblings. Thus, this question’s wording proved difficult for the students, who were unable to answer correctly. Lastly, question 6 had a 50% failure rate because it required students to simultaneously attend to three criteria, and for some students it was hard to remember all three criteria to find the answer.

Table 1. Percentages of students’ correct responses on probability questions

What is the probability that a student ...	Correct answers	Percentage of students who answered correctly
1. has black eyes?	2/14	(100%)
2. has brown eyes?	5/14	(100%)
3. has at least one sibling and at least one pet?	14/14	(100%)
4. is female and has black hair?	5/14	(62.5%)
5. has more than 3 siblings and more than 3 pets?	0	(87.5%)
6. has brown eyes, black hair and less than 4 siblings?	2/14	(50%)
7. has brown eyes and no siblings?	0	(87.5%)
8. has at least 3 pets and at least 2 siblings?	1/14	(25%)
9. is male and has black eyes and blonde hair?	1/14	(100%)
10. has more than 4 pets, no siblings and brown hair?	0	(100%)
11. has no more than 2 pets and no more than 2 siblings?	3/14	(0%)
12. has green eyes and is female?	2/14	(62.5%)

Example from students’ work with InspireData[©]

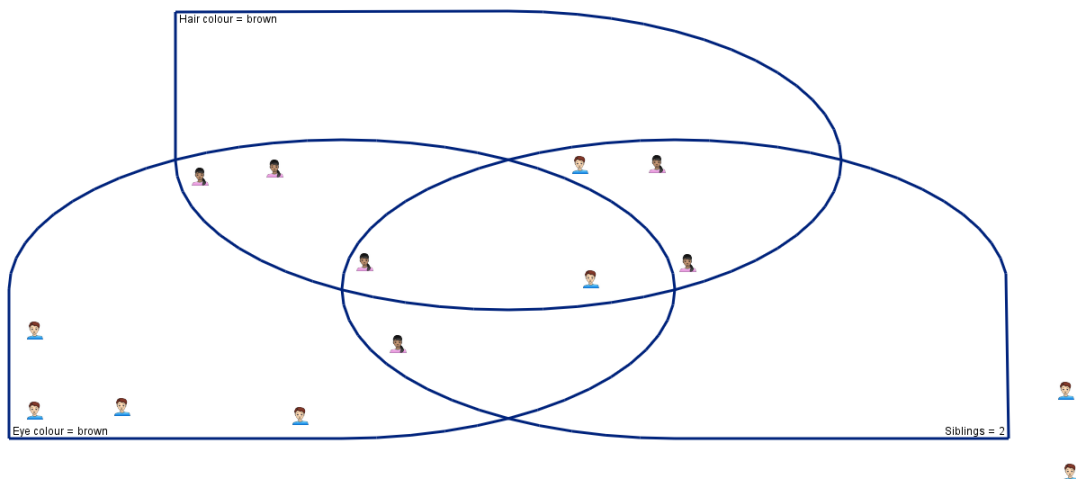


Figure 1. Students’ use of Venn diagrams for hair colour, eye colour and number of siblings

CONCLUSION

The qualitative methodology employed in this case study, its small scale, and its limited geographical nature, mean that generalizations to cases that are not very similar should be done cautiously. However, the study findings do suggest that the adoption of a hands-on, project-based approach to statistics does have the potential to enhance mathematics instruction by making statistical reasoning accessible to young learners. Moreover, there are strong indications in the study to support the belief that utilization of the affordances provided by a dynamic statistics

software such as InspireData[®], can indeed scaffold and extend children's informal stochastic reasoning (Ben-Zvi, 2006) by encouraging them to build, refine, and reorganize their intuitive understandings about statistics.

The findings of this study indicate that the use of a dynamic software tool like InspireData[®], in combination with suitable curricula and other supporting material, can provide an inquiry-based learning environment through which genuine endeavours with data can start at a very young age. Through exploration and dynamic visualization of authentic data, students can build informal understanding of basic statistical and probabilistic concepts and develop a strong conceptual base on which to later build a more formal study. Investigating, analysing, and representing data can also help students extend their understanding of other key mathematics concepts (e.g. fractions, percentages), as in this case study they were asked to write probabilities in both fraction and percentage form.

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