

Virtual Environment Support of Statistical Literacy at Basic Education

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INTRODUCTION

Recognition of the importance of statistical thinking in promoting skills and competencies necessary for the exercise of citizenship made the Ministry of Education of Brazil, through the National Curriculum Parameters (PCN), incorporate basic concepts of probability and statistics in the mathematics curriculum for all the series of Basic Education (Brazil, 1997, 1998, 2002).

However, the inclusion of effective teaching of probability and statistics in the school faces major challenges: the training of teachers, who in their initial training either did not study this content or did so without working on the aspects related to the teaching of statistics, due to the scarcity of materials— textbooks and computer software, among others (Cazorla, 2006).

Thinking about these educational barriers, in 2006, a group of statistics educators from universities in Brazil began developing sequences of Probability and Statistics, aiming to contribute to the development of statistical literacy and scientific thought. These sequences of teaching activities use interdisciplinary contents, contextualized within the school environment, exploring the cognitive aspects of learning and those related to the development of a critical awareness of the use of natural resources and a respect for diversity.

At first, some of these didactical sequences were designed to be done only in a paper and

pencil learning environment, and some others also using a computing environment, but just spreadsheets.

In fact, in the process of teaching and learning probability and statistics, working in a paper and pencil environment is crucial for students to experience each step of the statistical procedures. However, the teacher must be aware of the fact that, according to Kataoka and Cazorla (2010), Statistics is a science that aims to uncover patterns underlying the data and, therefore, uses techniques involving complicated calculations that involve large amounts of data. So, working only in this learning environment can make the activities strenuous for students, bypassing the main focus, which is the critical interpretation of the results. The use of a limited amount of data for students to learn the algorithms of the calculation of the statistical measures can function as a didactic strategy. However, this strategy prevents the students from understand the inferential power of these measures. It thus become necessary to increase the database, which necessarily involves the use of computational resources.

In this context, in 2008, a group of statistics educators began developing the Virtual Environment to Support Statistics Literacy Basic Education (AVALE-EB). The AVALE-EB is a virtual learning environment, free of charge, which currently provides ten didactical sequences (SE) to assist teachers in probability and statistics in basic education, in both paper and pencil and virtual learning environments. The aim of this paper is to present both the didactic aspects of AVALE-EB, using as an example the sequence of teaching called “Vitruvian Man,” and the technical aspects.

AVALE-EB: DIDACTICAL ASPECTS

The AVALE-EB is a research and development project of the State University of Santa Cruz, in collaboration with researchers from other universities, and aims to:

- develop and deliver a virtual learning environment, web-based, free, for the teaching of probability and statistics in basic education;
- provide didactical sequences (SE) in two environments: paper and pencil and virtual, contextualized in problem situations where students have an active participation;
- contribute to statistical literacy by using statistical and probabilistic concepts that enable the development of critical reading ability in the world of teachers and students of basic education;
- contribute to the scientific education of public school students and encourage their inclusion in a society which is increasingly computerized.

So far, the AVALE-EB offers five didactical sequences of Statistics (Vitruvian Man, Class Profile I, Class Profile II , Planet Water and Planet Light) and five of Probability (Buffon’s Needle Problem, Game of Discs, Game of Balls, Noodles’ Problem and Carlinha’s Random Walks). These activities follow the recommendations of the National Curriculum Parameters and its construction and validation is being made through the anthropological theory of didactics (Chevallard, 1992) and the ontosemiotic focus of cognition and mathematics instruction (Godino, 2002).

In the period from 2008 to 2010, the AVALE was financed by the Foundation for Research Support of Bahia (FAPESB) and constructed and validated by three multidisciplinary teams. The first team comprised statisticians and computer scientists (ECC), the second, statistics educators (EE), and the third, contributor teachers (PC) from public schools, working collaboratively. The ECC team was responsible for the computational development of AVALE, and the EE team for the definition and format of the content and methodology of the SE. The implementation in public

schools was the responsibility of the PC team, previously trained by the EE team.

Currently, AVALE-EB is financed by the Education Department of the State of Bahia, and is developed at the Anísio Teixeira Institute, which is the center for continuous training of teachers in the state. The team consists of ten statistics educators, three elementary school teachers, a scholarship for Undergraduate Research (graduate UESC-BA), two masters students (Graduate Program in Mathematics Education UNIBAN-SP), and a systems analyst. In this second phase, the AVALE-EB aims to finalize the adjustments of the computer system, producing tutorials, video lectures (theoretical and practical) of some SE, and to continue the validation and implementation process of the SE in public schools in the state of Bahia.

Development of SE in the paper and pencil environment – Vitruvian Man

As an example, we will briefly present how the SE “Vitruvian Man” works, which is already being implemented in schools. The estimated time of application is 400 minutes, divided into four meetings.

This SE has as its general objective to enable intradisciplinarity between mathematics and statistics, particularly with the concepts of the relationship between variables and functions, from the study of relationships between different parts of the human body, postulated by Leonardo Da Vinci. This SE has the following objectives:

- To encourage students to experience the cycle of scientific research: formulating a hypothesis, contextualization of the problem situation, collecting data, processing and analyzing data, and producing and communicating the results, using statistics as a guide.
- To analyze the patterns of relationships established between the anthropometric variables, using concepts and procedures which emphasize the inherent variability of the characteristics of the phenomena under study.
- To present the role of statistics in studying the relationships between the variables and its contribution in developing the concept of mathematical function.
- To present the intuitive notions of correlation and linear regression.
- To encourage the use of technological resources in learning scientific concepts.

This SE can be worked as an interdisciplinary and transversal project in partnership with teachers of biology, arts, ethics, and mathematics. In the paper and pencil environment, this SE covers five steps.

Step 1) Background of the problem situation

The Vitruvian Man is a famous drawing accompanying the notes by Leonardo da Vinci made around the year 1490 in one of his diaries. It is a naked male figure separately and simultaneously in two superimposed positions with arms entered in a circle and a square. The head is calculated as one-eighth of the total height.

To put the situation in context, the teacher can refer to several texts available on the Internet and ask students to investigate who was Vitruvius, Leonardo da Vinci, what anthropometric measurements are, and what are the relations established in the design of the Vitruvian Man.

Step 2) Formulation of hypotheses

Looking at the drawing, the teacher may suggest students to consider some relations of the human body, such as one foot is the width of four spans, the length of the outstretched arms of a man is equal to his height, maximum width of shoulders is one fourth the height of a man: the

length of the hand is one tenth of the height of a man, among others. Other hypotheses can be formulated as: Do women generally have their anthropometric measures smaller than those of men? Is there any age group in which this “superiority” of the male is reversed? Does the relationship between human body parts change over age?

Step 3) Defining the variables

Once the research questions are established, it is possible to define the variables that will be collected. In this example the variables are: gender, age, height, arm span, shoulder width, hand length, and head circumference.

Step 4) Collect and record the data

The teacher should take the students’ measures using sewing tape, ruler, and tape measures. Then they must record the data on a sheet of paper glued to the wall (Figure 1).

Figure 1. Collecting and recording data in the SE Vitruvian Man



Step 5) Calculation of statistical measures and constructing tables and graphs

In this learning environment, the teacher can select one or two variables to be investigated, leaving the other variables to be explored in the virtual environment. It is noteworthy that it is interesting that the teacher asks the students to examine the variables both using the data of the whole class, and by gender. In the case of this SE, students should also explore bivariate relationships in order to assess the research questions formulated in the second stage.

Several statistical measures can be explored, but the teacher should assess what is most appropriate for their students, as well as how they can be addressed (Figure 2). For example, to work with statistical measures such as the median, mode, and quartiles, as well as discussing the variability of anthropometric measurements, a human dotplot can be used (Figure 3).

Figure 2. Recording, calculating statistical measures and drawing graphs

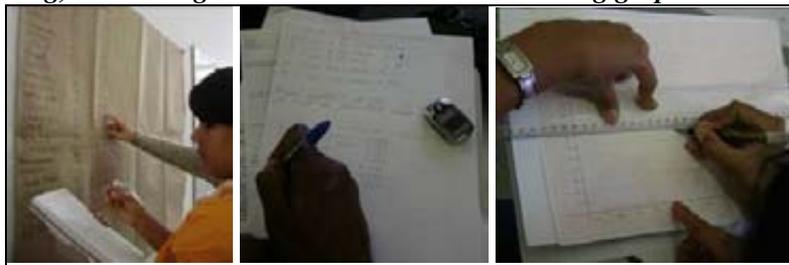


Figure 3. Human dotplot of height and number of shoes



In addition to the statistical measures, students can draw various types of graphs, such as their own dotplot, histogram, boxplot, pie charts, bar and scatter plot.

Development of the learning sequence Vitruvian Man in the virtual environment AVALE-EB

The homepage of AVALE-EB is composed of general project information subdivided into menus and informative submenus. All available sequences are located in the link sequences of education (SE), (Figure 4).

To begin working with the AVALE - EB in the classroom, initially, the teacher must register, and must then register the classes (Figure 5). In the case of the SE “Vitruvian Man,” along with five variables already included (gender, age, height, shoe, size) the teacher may optionally enroll more than two variables, eg, shoulder width and head circumference (Figure 6). In addition, with the class registered the teacher can edit the information of a student or delete records.

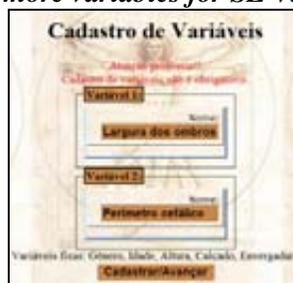
Figure 4. AVALE - EB's home screen with the available SE (<http://avale.uesc.br>)



Figure 5. Screens for registration of teachers and classes



Figure 6. Screens for recording two more variables for SE Vitruvian Man



In a computer lab with Internet access, students should register by selecting their teacher and class, and then entering the system (Figure 7).

Figure 7. Screen for register and entry to AVALE- EB SE Vitruvian Man



Then the system generates a customized data entry, online, in which each student enters personal data and sends it (Figure 8). After sending the data the student can check if their data are correct and, if necessary, correct them. At this point the system feeds, in real time, a spreadsheet with the data from all the students in the class (Figure 9).

Figure 8. Custom data entry

Figure 9. Databases of class

| Apellido | Genero | Idade | Altura | Calçado | Envergadura | largura_ombro | perimetro_cefalica |
|----------------|--------|-------|--------|---------|-------------|---------------|--------------------|
| edison | M | 14 | 160 | 42 | 173 | 38 | 53 |
| carlos a. | M | 14 | 160 | 42 | 174 | 38 | 53 |
| carlos | M | 13 | 165 | 39 | 168 | 43 | 56 |
| luan a. | M | 16 | 179 | 42 | 176 | 47 | 57 |
| diego | F | 12 | 166 | 38 | 169 | 44 | 54 |
| felipe | M | 13 | 162 | 38 | 167 | 44 | 53 |
| matheus | F | 16 | 173 | 39 | 171 | 43 | 53 |
| marcelo | F | 14 | 163 | 37 | 161 | 43 | 54 |
| carlos a. | M | 12 | 176 | 43 | 182 | 41 | 57 |
| gabriel | M | 13 | 174 | 40 | 174 | 40 | 57 |
| sergio | M | 13 | 176 | 41 | 170 | 40 | 55 |
| bruno | M | 14 | 166 | 37 | 159 | 44 | 57 |
| joatão | M | 14 | 184 | 41 | 181 | 45 | 58 |
| angelica | F | 15 | 157 | 35 | 155 | 46 | 53 |
| rita | F | 14 | 165 | 37 | 170 | 47 | 58 |
| carla | F | 16 | 166 | 37 | 167 | 39 | 54 |
| maria carolina | F | 11 | 162 | 37 | 162 | 39 | 56 |

With the class registered, the teacher can ask students to determine the statistical measures for both the variables already explored in the paper and pencil environment (for comparison), and for the others, empowering the analysis (Figure 10).

Figure 10. Statistical measures available in the SE Vitruvian Man

The statistical measures available can be calculated for the whole class or for a subgroup: mean, median, mode, total amplitude (TA), minimum, maximum, standard deviation (SD), variance,

coefficient of variation (CV) and quantiles (Figure 11). Besides the student may request a measurement each time for each variable. It is possible to get an overall summary (Figure 12).

Figure 11. Average height for the class and by gender

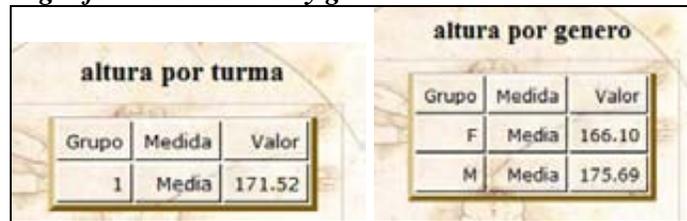


Figure 12. Summary of global variables in the Vitruvian Man SE

| Variaveis | Media | Mediana | DP | CV | Minimo | Maximo | AT |
|--------------------|--------|---------|------|-------|--------|--------|----|
| idade | 13.78 | 14 | 1.38 | 10.03 | 11 | 16 | 5 |
| altura | 171.52 | 173 | 7.55 | 4.40 | 157 | 184 | 27 |
| calcado | 39.22 | 39 | 2.21 | 5.62 | 35 | 43 | 8 |
| esvergadura | 170.96 | 171 | 7.78 | 4.55 | 155 | 187 | 32 |
| largura_Ombro | 42.78 | 44 | 3.61 | 8.44 | 37 | 48 | 11 |
| perimetro_cefalico | 55.48 | 55 | 1.66 | 3.00 | 53 | 58 | 5 |

AVALE offers traditional graphics, such as sectors, bars, boxplot, dotplot (Figure 13), and in addition to these graphs, AVALE can also draw animated dotplot and dotboxplot (Figure 14).

Figure 13. Charts available in the SE Vitruvian Man

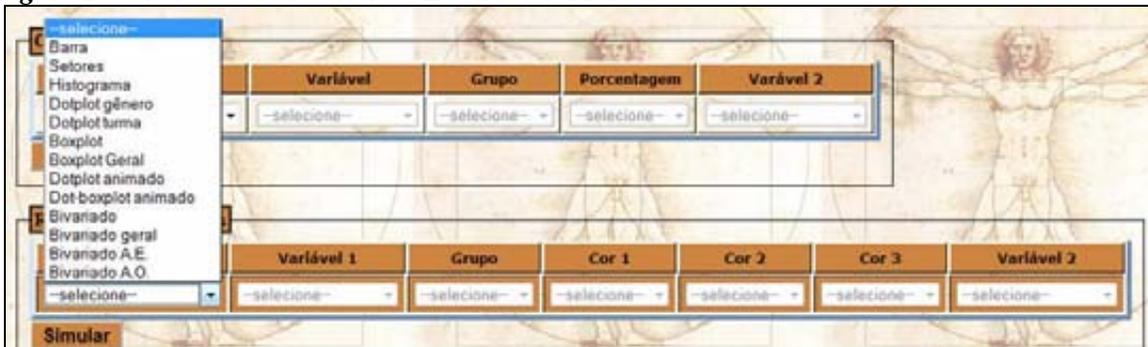
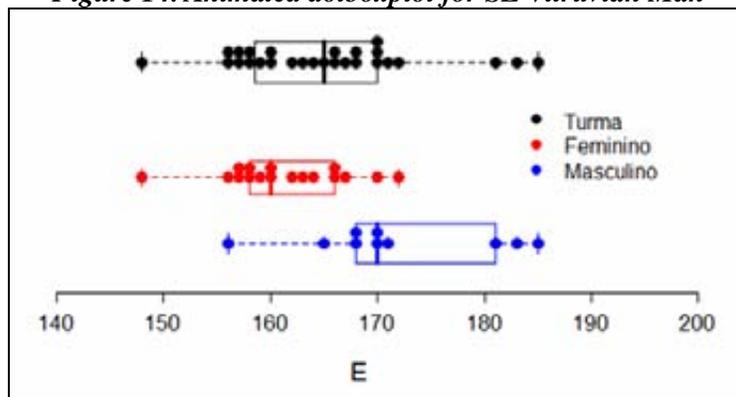


Figure 14. Animated dotboxplot for SE Vitruvian Man



After the analysis has been conducted in both environments, the teacher should ask students to generate the reports, describing the whole process of reasoning to defend their hypothesis. This phase of data interpretation is a very important moment for students, to answer the research questions initially proposed. Then they report the results to the whole class and/or to school community, using posters or a portfolio. When communicating the results, students should choose measures and graphics that are more meaningful, i.e., those which best represent the data set collected with a choice of statistical measures, graphs, the systematization of the measures in summary tables, inserted in graphic itself, or even within the text (Figure 15).

Figure 15. Conjecturing, arguing, defending hypotheses and communicating results



AVALE-EB: TECHNICAL ASPECTS

General aspects

The AVALE – EB is free software developed for web programming languages using HTML, CSS, PHP and JavaScript. The languages HTML and CSS are for visual presentation of the system: the HTML conveys the information, i.e., the portion of the site responsible for the content displayed on it. CSS is the design, a language that changes the appearance of HTML, i.e., a standard for formatting (Web Standards) which allows overcoming the limitations imposed by HTML.

JavaScript is a scripting language directly interpreted by the user's browser and is used to validate forms and perform actions in real time. PHP, which is a free interpreted language, is used for the manipulation of data. Its main advantages are its speed, robustness, and portability.

All system information is stored in a MySQL database, using SQL. This is a complete database, robust and extremely fast. Additionally, the Apache server is used to provide the web hosting service.

Joomla, a CMS (Content Management System), is used for management of the site content. Joomla is a framework, a “skeleton” of the website/portal, pre-programmed with basic resources, maintenance and administration already available. It is an open source project that aims at facilitating the maintenance of a site and/or complex portals.

The teaching sequences are developed in PHP as part of the site (Figure 4), which also has some SE with simulations developed with Java (an object-oriented, portable programming language). These simulations can be performed directly on the site page without having to download anything on the client's computer since they use network resources.

Operation of didactical sequences

Taking the SE as a starting point, all web development and data storage is in that category. The system was developed in a structured way and divided into packages: connection to the database, JavaScript scripts.

Initially the registration of the teacher should be done, and for this an HTML form is

presented on the screen, and validated by JavaScript, verifying the required fields (Figure 5). Then the data is passed through PHP to the MySQL database, where it is stored and from which it can be retrieved later. With a teacher already registered, the inclusion of new groups is possible, and they, too, can be included directly into the database through PHP (Figure 5).

On registration of the student, besides the login and password fields, the teacher and the class where the student belongs should be selected; a teacher's search is carried out by a text field that performs the search at run time using AJAX technology (the methodical use of technologies such as JavaScript and XML makes the web pages more interactive), returning a list of teachers that contain the given word in text field; the same thing happens with the teacher's classes (Figure 7).

The identification of each user's system is made by means of two variables, the "nickname" and the class, so there is no restriction arising from the names of the system users belonging to other classes. The input of the system consists of an insert form of statistical or probabilistic data. Each item to be inserted should be sent to update. From there the data is inserted into the table for the SE in the MySQL database (Figure 8). For a previously registered user, the system only updates the values.

The AVALE - EB system stores the data in real time, and after all students have entered their data, a single table is generated with the data class (Figure 9) which, from now on, serves as a source of information for making calculations and drawing the displayed graphics (Figures 10 to 13). By the time the full class is accessed, a query to the database class is made, and generates a file with the extension ".txt". This file imports all the data in a certain format for the recognition of the R software.

The R software is a language and an integrated development environment for statistical calculations and graphs. After the automatic creation of the file, the chart or calculation to build must be chosen, and the user is directed to a page where the data filters are available for the chosen option. Then a call is made to the system (a shell command to run external program) directly from the PHP page, using specific functions of language itself, running the script referred to.

This script processes the data input and generates an HTML page as output with the expected result. After this process, the system makes the call on that page as a pop-up window (it is recommended to add an exception for the pop-ups in the AVALE – EB page). If it wasn't possible to open the pop-up, AVALE – EB leads the user to the result by the current page by changing the action of the link "exit" on the results page, making it forward to the previous page.

FINAL CONSIDERATIONS

According to Kataoka and Cazorla (2010), the results of applications of the didactical sequences using AVALE – EB in schools show that students remain motivated and involved, give meaning to concepts, managing to read and interpret graphs and draw conclusions from statistics. Another important factor is to understand how these students have skills with the use of computers and how they engage quickly with the computer system. So, working with didactical sequences structured along a dimension of scientific research and social practice, we will be contributing to the development of statistical literacy, scientific spirit and to the formation of critical citizens.

Currently the system is being finalized to make it available to the public. Once the AVALE – EB is fully operational and functional, it will be submitted to the government of Brazil for assessment, evaluation and possible adoption by the public school systems. There are also the goals

of translating it into Spanish and English, and to search for national and international partnerships in order to maximize its use. Finally, we hope this virtual environment can help in popularizing the teaching of probability and statistics at the school level, in developing positive attitudes of students towards statistics and mathematics, as well as promoting digital inclusion, and that the AVALE-EB can find large scale use within schools.

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ABSTRACT

This paper presents the Virtual Environment Support of Statistical Literacy at Basic Education (AVALE-EB) is being developed by researchers at State University of Santa Cruz, in collaboration with researchers from some other universities and basic education teachers. AVALE-EB provides for free, on the Web, 10 didactic sequences to help teachers on teaching Probability and Statistics. AVALE-EB aims to contribute to the development statistics literacy and scientific thinking, using contextualized activities at school, with topics that explore the cognitive aspects, and also subjects related to develop a critic conscience about using natural resources or about respecting diversity. This environment is being constructed on the Linux platform, with the open source code software R, and provides a customized input-data system, creating a dynamic electronic sheet in real time, and providing statistics tools for data treatment. The system is now being finalized in order to be available to general public, to be translated into Spanish and English, and we are looking for national and international partnerships to support its wide use. Finally, we describe how AVALE-EB may contribute to teaching Probability and Statistics at school, to developing positive attitudes towards statistics, increasing digital inclusion among students, and be widely used within the school.