

# **Improving the learning of statistics with computer-based exercises.**

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## **Abstract**

CAST is a collection of e-learning books that make extensive use of interactive and dynamic diagrams to teach statistics. Over 100 computer-based exercises have recently been added and each has a random component that allows it to be repeated until the targeted concept is mastered. Feedback is given about wrong answers and each exercise has a "Tell me" button to explain the correct answer. These CAST exercises have recently been used in the applied statistics MSc at Maseno University.

The paper outlines the advantages for students from including this sort of exercises in their learning. Some of the difficulties encountered are described as are plans for future use of the exercises. A new feature of CAST allows for on-line class tests.

## **Introduction**

CAST stands for "Computer Assisted Statistics Textbooks" and is a collection of electronic textbooks (e-books) that are designed to be read on-line, rather than being printed. E-books can use dynamic and interactive graphics that are more effective for teaching than their static counterparts in paper textbooks, and most CAST pages include an animation, simulation or other sort of dynamic display to help explain key concepts.

For many students, reading a paper textbook is a passive experience. In contrast, CAST's interactive components make it a form of active learning that helps to keep the students' interest and hence improve their learning experience (Meyer and Jones, 1993).

CAST was first released in 2000 and has been expanded and improved with the regular release of new editions since then. In addition to three introductory e-books, two advanced e-books have been added and customised e-books have been created for specific groups of users. CAST 4.0 will be released later in 2009.

CAST is data focussed, and includes many data sets. In the public e-books, the examples are from a wide range of applications but are mostly aimed at readers from the developed world. More recently, customised e-books have been written with collaboration from staff at the University of Nairobi and others, as companions for courses developed specifically for use in Africa and these include more examples from Africa. The latest installer for the African release of CAST (currently a beta version 4.0) can be downloaded from:

[http://castAdmin2.massey.ac.nz/download/CAST\\_for\\_Africa\\_installer.exe](http://castAdmin2.massey.ac.nz/download/CAST_for_Africa_installer.exe)

CAST runs within a web browser and may be used over the web by users with fast internet, but it may also be downloaded, or installed from a CD/DVD to run locally without need for an internet connection. It can be used without charge under a "Creative Commons Licence" that allows users to freely download, copy and use CAST, provided it is fully attributed to the

author (Doug Stirling). From release 4.0, there will be no requirement to register an email address or obtain a PIN code to use CAST.

The cost of ordinary textbooks is often limiting for students perhaps particularly in Africa, and this makes resources such as CAST particularly welcome. Recent versions are however much more than just a series of e-books. CAST includes lecturers' e-books that only contain the interactive diagrams, designed so trainers can easily use them within their presentations. Presentations and other documents can also contain links to specific pages within CAST e-books.

Another recent addition is a series of exercises that fill the role of the exercises in a conventional textbook, but whose interactive nature makes them a far more useful. Their use is described here.

### ***Exercises in CAST***

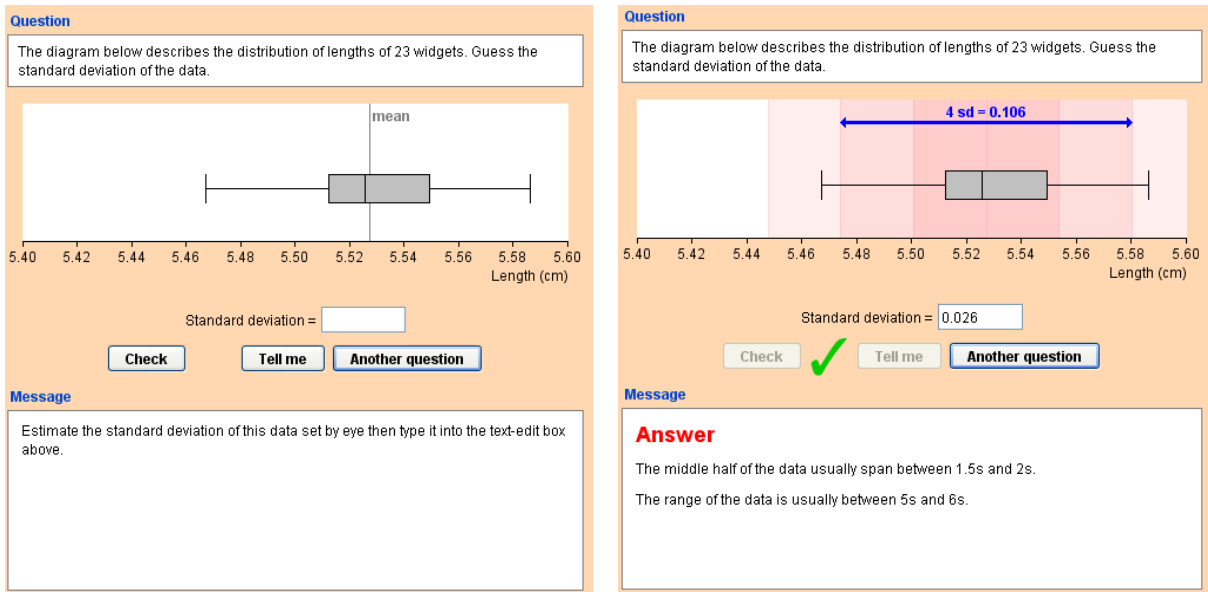
Much of the training for many statistics students involves listening to lectures and reading books and is relatively passive. Use of the interactive diagrams in the main CAST e-books makes their use a little more active but exercises are a particularly effective form of active learning. They make students think and recall information and are therefore more intense than many other ways of studying, Stirling (2008a).

Many statistics textbooks therefore include a series of exercises at the end of each section or chapter. They often give solutions, but these may be as little as a statement, or number, signifying the correct answer. There is rarely much feedback to help the student who does not know the approach to use, or who gets the wrong answer.

On-line resources give much more potential for exercises with accompanying support for students. However, this has rarely been realised in on-line statistical resources. Some, e.g. StatWeb, Hulme et al, (2008) do not include exercises, while others, e.g. Hyperstat, Lane, (2008) have questions with the same limitations as paper-based textbooks.

CAST 4.0 includes a series of exercises that attempt to maximise the benefit to students of using an interactive resource to learn statistical concepts. Each exercise is a Java applet, like the other dynamic diagrams in CAST, and the use of this powerful programming environment allows great flexibility in the format of questions and the potential for constructive feedback.

Figure. 1 Example of a CAST exercise



For example, the diagram on the left in Figure 1 asks the student to estimate the standard deviation,  $s$ , from a picture of the boxplot. All exercises include a “Tell me” button, which can be used if students are not sure what is required or how to obtain the answer. The diagram on the right in Figure 1 shows what happens here, when this button is pressed.

Each exercise also includes a message box, and in Figure 1 it gives information on the relationship between the parts of the boxplot and the standard deviation. The same information is also shown by the shading in the diagram.

Usually the student does not press the “Tell me” button, but types an estimate into the box labelled “Standard deviation =”, and then presses the Check button. Figure 2 gives examples of the feedback for the same question as Figure 1, when other answers are given. The actual diagram is shaded in the same way as on the right hand side of Figure 1 to provide more information, and the student is free to try the same exercise again, or press the “Tell me” button.

Figure 2 Example as in Figure 1, but with wrong answers



Different exercises give a wide variety of tasks to the student and a few examples are shown in Figures 3 to 6.

Figure 3 asks for a cumulative percentage and requires the student to drag the vertical red line to the value in the question, day 155, and this automatically updates the proportion under the diagram. The student must translate this into a percentage and type the value underneath.

Figure 3 Question requiring interaction with a cumulative distribution

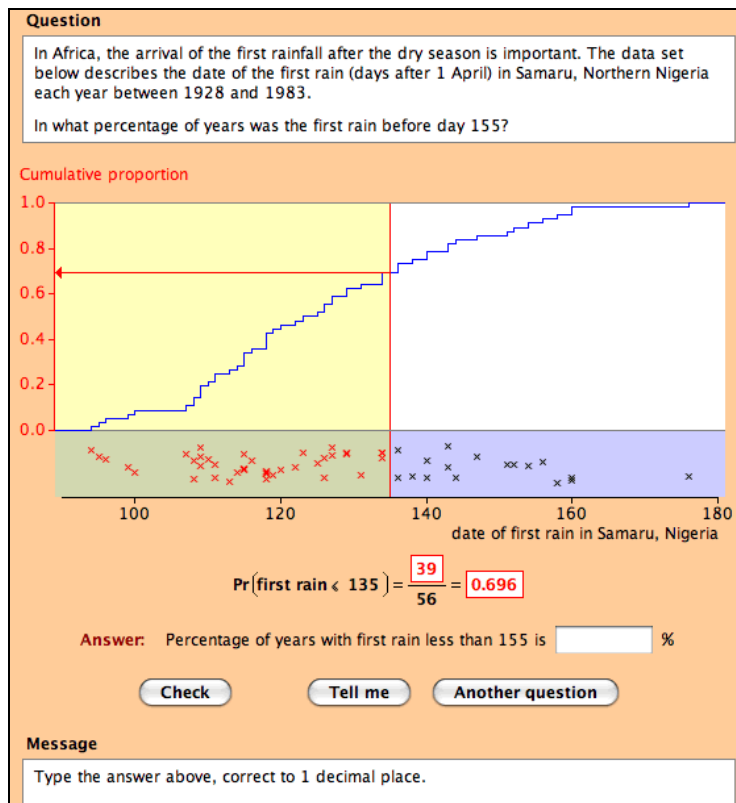
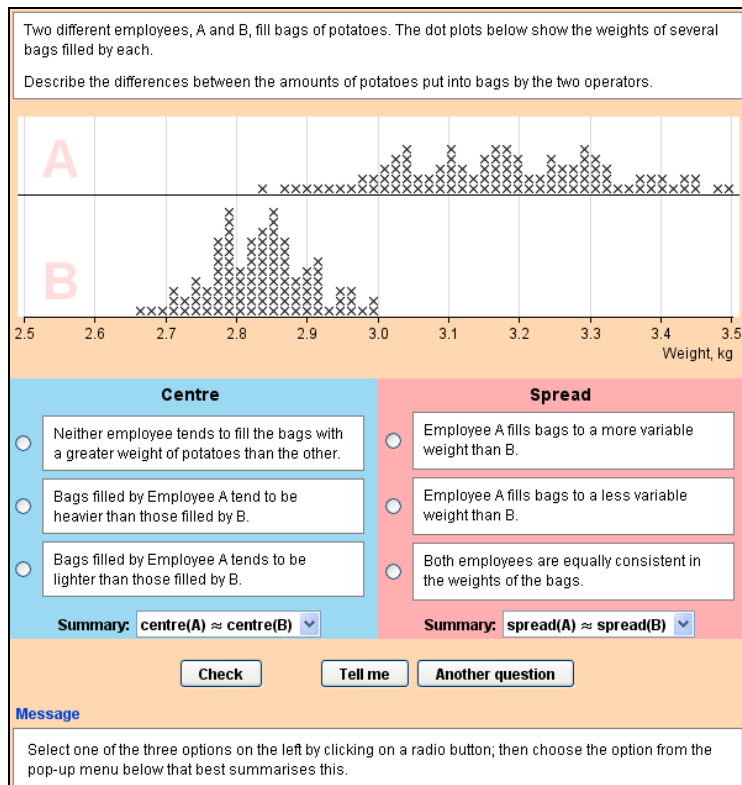


Figure 4 is a simple question to compare the average and spread of two distributions. The student has to answer four questions here, two from the multiple choice buttons and the others from the drop-down lists.

Figure 4 Question requiring several multiple choice answers



The exercise in Figure 5 assesses knowledge about different types of measurement and again involves four sub-questions. Figure 5 shows the feedback after "Check" is clicked when three of the answers are correct but the fourth is wrong. CAST has shaded the wrong answer to indicate where the error has occurred and has given the solution, with an explanation.

Figure 5 Question showing the feedback, after a partially wrong answer

**Question**

Monthly climate data was collected from weather stations in each of the 93 districts in a country over a period of 20 years. The resulting data set therefore has 33,480 records, one for each district and month. Each of these records contains various climatic and other measurements. Use the pop-up menus to classify each of the following four measurements.

**Month**  
One of the months January, February, ..., December  
Categorical ordinal

**Frost days**  
Number of days with frost in the month  
Numerical discrete

**Season**  
Either Spring, Summer, Autumn or Winter  
Categorical nominal

**Max temperature**  
Maximum temperature in the month, rounded to the nearest degree C  
Numerical continuous

Check **X** Tell me Another question

**Message**

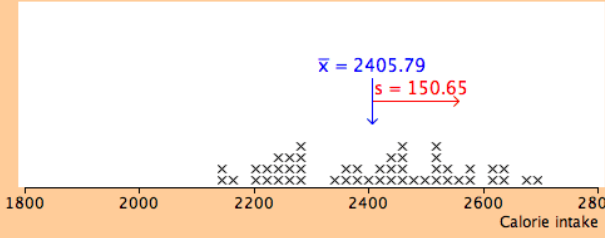
**Wrong!**  
Season: There is an ordering of the seasons so this is an ordinal categorical variable.

The exercise in Figure 6 requires the student to do a calculation, and a template is supplied within the exercise to help with the arithmetic. The student should enter the appropriate values for  $s/\sqrt{n}$  to provide the answer and Figure 6 shows the output after typing the correct answer and clicking "Check".

Figure 6 Question demanding the use of a formula

**Question**

The calorie intake was recorded from a sample of  $n=49$  adults in an African village. What is the standard error of the mean calorie intake per person in the village?



$\bar{x} = 2405.79$   
 $s = 150.65$

Standard error =  $\frac{150.65}{7} = 21.52$  calories

Standard error = 21.52 calories

Check **✓** Tell me Another question

**Message**

**Answer**

The standard error of the mean is the sample standard deviation divided by the square root of the sample size,

$$se(\bar{x}) = \frac{150.65}{\sqrt{49}}$$

A key feature of every exercise is an "Another question" button. This randomises as many aspects of the question as possible, including the context, data sets, ordering of multiple choice options and other parts of the question. For example, in Figure 1 the questions alternate between giving histograms and boxplots. This randomisation feature allows the student to practice a task until they have understood the concept being taught.


### Using the exercises

In the past year the CAST exercises have been used, both in short courses to agricultural researchers, and also for the statistics MSc students at Maseno University (Kenya). In both cases, a major use was to check that key concepts that need to be assumed were understood. The problem was usually that participants had been taught the ideas, but often through formulae, and sometimes without understanding the underlying concepts.

For the short courses the exercises were usually presented to the whole group together. A simple example that typified the difference between a concept and a formula is shown in Figure 7.

Figure 7 An exercise to check that students can interpret the standard deviation

The photograph below shows a few of a brood of recently born chickens.  
The mean weight of the chickens is 40 gm; guess their approximate standard deviation.



Approx standard deviation is  gm

**Message**  
Guess the standard deviation of the weights of the chickens then type it into the text-edit box above.

A number of participants were asked for a value, before anything was typed. Then all the guesses can be tried in turn. In the above example, typing 4gm gives the response:

“Good! The standard deviation that you specified is a reasonable value for the weights of the chickens. It is possible that about 5% of chickens might have weights outside the range 32 to 48 gm (i.e.  $\mu \pm 2\sigma$ )”

This question gives a positive response for any value between 2gms and 6gms. Typing 1gm gives the response:

“Not a reasonable value! It is likely that more than 5% of the chickens will have weights outside the range 38 to 42 gm (i.e.  $\mu \pm 2\sigma$ )”

Other questions from this same exercise ask for weights of supporters at a football match, heights of children in a group, and widths of a set of books etc.

At Maseno University an initial problem was the lack of suitable computers, even for the MSc students, but this was overcome, partly by the students themselves, as they realised the benefits for their learning from easy access to a computer.

Some students were not computer literate at the start of their course. This was sometimes despite taking an undergraduate degree in statistics, which (amazingly) is still taught in some Universities with little or no use of the computer for their statistics work. Often this was the case with students who had taken their first degree some years ago.

These students had quickly to be able to master the use of CAST as well as a statistics package (Genstat). They found CAST easy, and hence were quickly able to use CAST to learn statistics, rather than to support their computing skills. They later found their skills using the CAST applets also made it easy to use a web browser over the internet in later tasks. Those who were computer literate found CAST very easy to use.

Students who used the exercises had earlier become familiar with the use of CAST applets, when reading the text. However, their initial performance at the exercises showed that they had often failed to understand the key concepts that the applets were illustrating. The exercises have added a useful dimension to the student's learning. It was particularly useful that any exercise can be attempted repeatedly, until it becomes easy since this only happens when the underlying concept has been fully understood.

## ***Future***

At Maseno CAST has so far only been used with the postgraduate students and they have found it to be extremely useful. This is, in some ways, an indictment of the undergraduate teaching at some Universities, because the materials in CAST are almost all intended for undergraduate students. However, often statistics has been taught in a relatively theoretical way that has not helped the students to be able to understand the concepts or to be able to apply the ideas taught.

Hence the next step is to use CAST, including the exercises with the undergraduate statistics students. This will make a greater demand on the University computer labs, but it is also useful to show that they are needed for other activities than data analysis.

A new addition to CAST that is currently under development is the use of the questions from the exercises in a test format. The testing system must be installed on a local web server and is, as yet, relatively undocumented. The test questions are identical to those in the exercises but without buttons to check the answer or give another version of the question and tests can be relatively easily created as a selection of these questions. Tests can be used by students as a learning exercise to assess their own skills and it is possible to allow them to be taken a number of times. Alternatively, the marks can be recorded as part of the formal assessment of the students.

One benefit of the full set of resources, i.e. the books for reading and interaction, the exercises, and the tests, is that they use a framework that becomes progressively familiar to the students. For the staff, the use of these tests provides an environment that is much richer than simple multiple choice questions, but remains one that can be marked automatically.

## **References**

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