

A Web-based Tool For The Analysis Of Concept Inventory Data

Joseph P Beuckman¹, Scott V Franklin² and Rebecca S Lindell¹

¹*Southern Illinois University Edwardsville*

²*Rochester Institute of Technology*

Abstract. “FOCIA” stands for Free Online Concept Inventory Analyzer. FOCIA, our new web-based tool will allow teachers and researchers in any location to upload their test data and instantly receive a complete analysis report. Analyses included with this tool are basic test statistics, Traditional Item Analysis, Concentration Analysis, Model Analysis Theory results, pre and post test comparison, including the calculations of gain, normalized change and effect size. The tool currently analyzes data from the Lunar Phases Concept Inventory (LPCI), the Force Concept Inventory (FCI), the Astronomy Diagnostic Test (ADT), the Force and Motion Concept Inventory (FMCE) and generically, any multiple choice test. It will be expanded to analyze data from other commonly utilized concept inventories in the PER community and, from user-designed and uploaded tools. In this paper, we will discuss the development of this analysis tool including some technical details of implementation and a description of what is available for use. Instructors and researchers are encouraged to use the latest version of the analysis tool via our website, <http://www.sciedures.org>.

Keywords: FOCIA, Web Analysis, concept inventory, item analysis, concentration analysis, model analysis

PACS: 01.40.Fk

INTRODUCTION

The last few years in education research have brought about somewhat sophisticated experimental analysis methods for interpreting student assessment data. The new methods typically require tedious, repetitive calculations that lend themselves readily to automation. At present, the methods are typically implemented by a combination of hand-manipulation of the data in spreadsheet software, mathematics software and graphics software. In FOCIA, we automate as completely as possible this analysis including several experimental data analysis techniques, as well as more traditional test analysis techniques and to provide wide access to our new tool with the overarching goals:

- To give educators and researchers instant access to the data analysis methods
- To accelerate the development of these and other new methods of assessment.

This paper presents the tool with some technical description of its implementation, examples of output and future directions.

FOCIA TECHNICAL DESCRIPTION

FOCIA makes sophisticated analyses of common and experimental test data and reports the results all via the World Wide Web. We use PHP as our programming language. PHP (recursive acronym for "PHP: Hypertext Preprocessor")¹ is a general purpose scripting language that works on a web server to provide HTTP (Hyper Text Transfer Protocol) content to a user's computer and is readily integrable with relational databases.

Several types of stored data are required as inputs to perform item, concentration and model analysis. There are the concept space structure, the concept inventory structure and content and the inventory result (classroom) data on which to perform the analysis.

The data comprising the concept space and concept inventory are relatively static. Changes to a concept space or concept inventory are only made by a researcher after analysis of potentially many datasets of class response data. To provide a portable storage

format for concept spaces and inventories, an XML (EXtensible Markup Language)² document type was devised to store and communicate them in a human-readable “ASCII text” format (Fig. 1).

```
<dimension name="Period of the Moon's orbit around the Earth" ID="0">
  <model name="null" ID="0"></model>
  <model name="approximately one month" ID="1" correct="yes"></model>
  <model name="less than one month" ID="2"></model>
  <model name="greater than one month" ID="3"></model>
</dimension>
```

FIGURE 1. The XML document format for marking up concept spaces includes, for example, this tag to describe a dimension of the LPCI³ concept space and the dimension’s four different conceptual models.

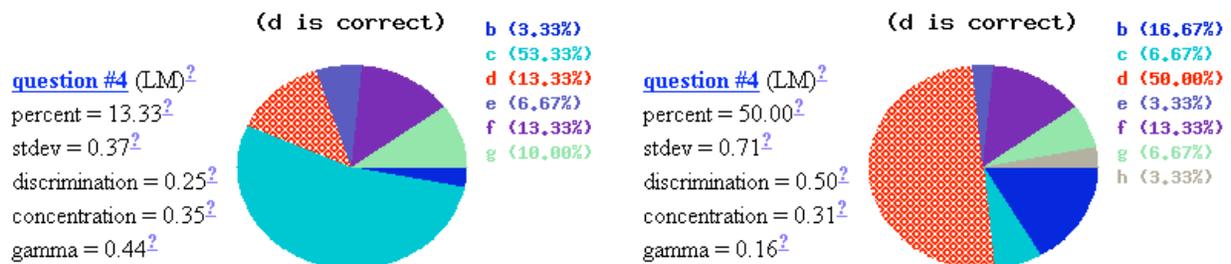


FIGURE 2. An example of the side-by-side response distribution data and graphics for pre-instruction versus post-instruction analysis for a particular item (in this case question #4). The superscript question marks at each figure hyperlink to an explanation of how that figure was calculated.

To facilitate efficient access to the concept space and inventory during the automated analysis, we store these relational data items in a minimized, SQL (Structured Query Language)⁴ database.

Inventory response data is parsed from the user’s delimited text files into arrays in program memory and stored in the user’s account on the website as a FOCIA “dataset.” The analysis is then performed on the response data using the information from SQL queries of the concept space and inventory database tables.

An object-oriented programming methodology is appropriate here to organize the structures of inventory result and analysis data. PHP classes for a “Record” (a single student’s response vector to the inventory) and an “Analyzer” (a group of Records with its analysis data) encapsulate the arrays and functions having to do with each. Several other classes implement portions of the interface and processing within the program.

USING FOCIA

We currently require users of FOCIA to register only so that they have a password-controlled account to maintain a separate, private space for their classroom data.

To use the automatic analysis, the user creates a “dataset” by uploading classroom result data for one of the inventories (or the generic multiple choice type) available within FOCIA. They then select which analysis results they want to be reported via an HTML form. Analysis is initiated with a button on the form.

The analysis is typically completed within a few seconds and result begin transfer to the web browser. The requested analysis results are organized and returned in a printable hypertext report. Numeric data are available as well as popular graphical representations (Fig. 3 and 4) and graphical representations unique to this program (Fig. 2).

ANALYSES CURRENTLY AVAILABLE

The tool currently analyzes data from the Lunar Phases Concept Inventory (LPCI), the Force Concept Inventory (FCI), the Astronomy Diagnostic Test (ADT), the Force and Motion Concept Inventory (FMCE) and, in a basic way, data from any multiple choice test.

The most difficult part of automating this analysis is properly importing the user class data. We have a model for this parser in place that works for a wide variety of text data file formats.

Automated item analysis⁷ for each item in a given inventory is currently available. Functions have been written to calculate difficulty, standard deviation of the mean and discrimination. A pie-chart showing response distribution for each item is available (Fig 2). It should be noted that item analysis can be performed on any multiple-choice test regardless of whether the test is a concept inventory with concept space and item to dimension mappings defined. Item analysis can be performed on ANY test data by selecting a “generic” option when creating its dataset.

Concentration analysis⁸ for each item has been implemented. Functions exist to calculate item concentration and gamma (concentration deviation) and report item score and concentration in the “L-M-H” coding system explained by Bao and Redish⁸. An automatically generated chart shows score vs. concentration for every item in an analyzed inventory (Fig. 3).

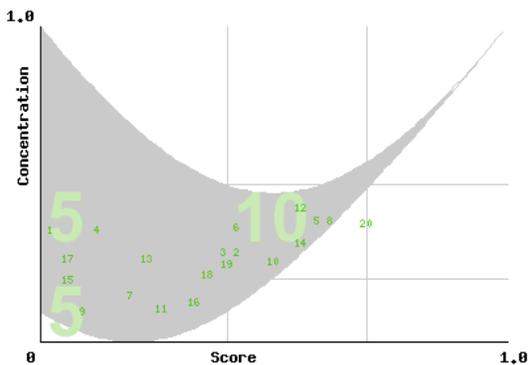


Figure 3. This plot of score versus concentration shows data from the 20 questions of the LPCI³ for anonymous sample data.⁶ The plot is divided into sections according to the L-M-H encoding⁸ and the number of data points in each section is displayed.

Performing model analysis⁹ requires several ordered manipulations of vectors containing the probabilities that a student within the dataset will choose a given concept model for each dimension in the concept space. Functions are in place to calculate the required probability vectors, then normalize to the “probability amplitude” vectors and produce the “density matrices.” The eigen-analysis of the density matrix is performed and analyzed for model use consistencies in the dataset. For binary comparisons between viable pairs of preferred models, “model plots” are generated programmatically (Fig. 4).

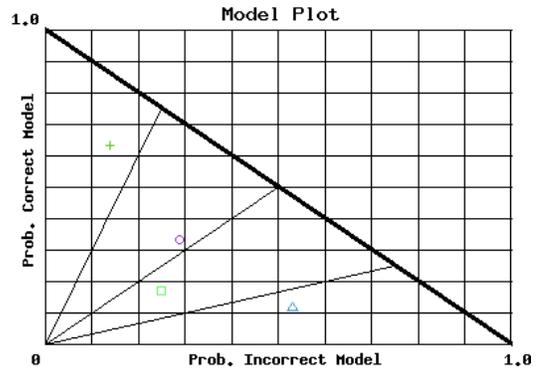


Figure 4. This example model plot⁵ shows results in each probability region from four separate instances of an inventory.

A mechanism is provided for performing two analyses side by side. This could be used to compare arbitrary datasets or to analyze a class’ performance pre-instruction versus post-instruction. When this type of analysis is selected, the program provides assistance with matching student records from the two datasets being analyzed. Plots of pre versus post instruction scores for each student can be generated as well as Hake plots¹⁰ and combined pre and post score versus concentration plots. A list of raw pre and post scores for each student is generated and each student in the list is hyperlinked to full pre and post instruction response listings for immediate examination.

FUTURE WORK

Eventually, we will allow users to upload independently developed concept spaces and inventories in the designated XML format. Users would be able to smoothly develop their own

inventories in this manner. We envision a system that would allow users public and private data areas for analysis and sharing results. This will require careful attention to privacy issues regarding the classroom datasets.

As mentioned, the parser code for class data files is a complicated area of the program as we want to be able to accept a wide variety of input formats. A means will be required for the user to efficiently ascertain whether their data has been imported correctly. It may be necessary to require of the user very specifically formatted data files. This is what we aim to avoid. We would like to include the ability to interpret Microsoft Excel format files in addition to the text data files we currently accept. We are studying the types of file formats most commonly used by testing services.

When users have functional access to the working analysis tool, we will focus on furthering the analyses available. We will expand and improve the current analyses and add other analyses as they become available or are requested, especially with regard to concept hierarchy analyses, another subject of our research. We will continue to improve the interface and add popularly requested features.

ACKNOWLEDGMENTS

We would like to acknowledge the Physics, Astronomy, Chemistry and Biology Education Research (PAC_BER) group at Southern Illinois University Edwardsville for the valuable insight they have contributed to this project. In addition, we would like to thank the SIUE College of Arts and Sciences and Department of Physics for providing the financial support for this paper.

REFERENCES

1. What is PHP?. <<http://www.php.net/>> Accessed May 2004
2. Introduction to XML . <http://www.w3schools.com/xml/xml_what.asp> Accessed June 2004
3. Lindel, Rebecca S. and Olson, James P. (2002) Developing the Lunar Phases Concept Inventory
4. Melton, J. SQL: The Standard And The Language. <<http://www.opengroup.org/public/tech/datam/sql.htm>> Accessed June 2004
5. Bao, L. Mathematical Features of Model Analysis
6. Note that one data point falls outside of the gray region. This is because the gray region represents the possible results for a Multiple Choice Single Response (MCSR) tool with exactly 5 possible responses for each item. The LPCI items vary in number of possible item responses.
7. Kehoe, Jerard (1995) Basic Item Analysis for Multiple-Choice Tests, *ERIC/AE Digest*
8. Bao, L. and Redish, E. F. (2001) Concentration Analysis: A Quantitative Assessment of Student States, Accepted for publication in *PERS of Am. J. Phys.*
9. Bao, L. and Redish, E. F. , Model Analysis: Modeling and Assessing the Dynamics of Student Learning, submitted to *JPER*
10. Hake, R. R. (1998). Interactive-engagement versus traditional methods: A six-thousand-student survey of mechanics test data for introductory physics courses. *American Journal of Physics*, 66(1), 64-74.