

THE RELATIONSHIP BETWEEN LEARNING STYLES AND THE COMPUTER-BASED INSTRUCTION SYSTEM PRECALC

Juan C. De Lemos, Alex Pelin, Jose Quiroz
Computer Science Department
Florida International University
Miami, Fl. 33199
E-Mail : DELEMOSJ@SOLIX.FIU.EDU

In this paper we introduce the PRECALC Project, a Computer-Based Instruction System developed at Florida International University. We present a description of the PRECALC project, including its design principles, its authoring tools and its hardware and software requirements. In addition, we describe the evaluation made to assess the effect of the CBI systems on students of different learning styles.

OVERVIEW OF THE PROJECT

The PRECALC project is a Computer Based Instruction course that covers the standard precalculus topics: conic sections, relations, functions, graphs, and polynomials. We have implemented 8 lessons (circle, ellipse, parabola, hyperbola, conic sections, relations, functions, graphs) and we will complete the polynomials lesson by mid December 1995.

The lessons are run on a computer and last two to three hours. Each lesson consists of a sequence of screens that present definitions, theorems, graphs, examples and exercises. At the start of each lesson, the student is presented with a lesson objective screen that describes the contents of the lesson. Then the student gets a menu that lists the sections of the lesson.

Each section covers a different topic. The first section, the Prerequisites, presents the information that the student must know to follow the lesson. Each lesson has 4 to 6 core sections, a Practice Problems section and a Progress Check section. The Practice Problems section contains a large set of problems based on the topics covered in the core sections. It acts as a reinforcement of the information presented in the core sections and helps the student to visualize and to understand the material. The last section is used for self-examination. It has 20 questions from the core area. Based on the student's answers, the system prescribes remedial exercises for the weak areas.

Each section is a sequence of screens. Each screen has a flow bar that allows the user to navigate through the lesson. The student can move to the next screen, go back to the previous screen, or put the lesson on standby and look at the terms or review the prerequisites. He/she can also get a menu to go to another section or to exit the lesson. In special cases the student can obtain hints for solving a problem.

All lessons are designed to appeal to the students who are unable to acquire the material through classical classroom presentations. We arrange the material to meet the

individual needs of the learner. We are concentrating on the physical elements needed for the visual, tactile, and kinesthetic users, because we believe that the auditory student has no problems with classical classroom teaching as long as the class periods are 45 minutes long and they have time to digest the contents of the lesson.

The Screens

The screens are the smallest unit of the lesson. We standardize the screens into three groups:

- question screens
- information screens
- menu screens

In each lesson, about 98% of the screens are either question or information screens. Each question and information screen contains:

- an identification bar
- a flow bar
- a status bar
- an information display
- a graph display area

The identification bar contains the name of the section, the name of the lesson, and the identification number of the screen. It is mainly used for maintenance purposes.

The flow bar allows the student to navigate through the lesson. He/she can go back, forward, get to the main menu, access the terms and the help sections, and get hints to certain exercises. Students can enter these selections through the keyboard or by using the mouse.

The status bar is a thermometer-like column displayed to the left of the screen. It shows how much of the section has been completed and how much remains to be done. The status bar is used in the core sections, the practice problems, and the progress check.

The information display area is one of the two main areas of the screen. Here we place the textual information. The student will also write his answers in this area. Depending on the screen, this area covers 45% to 80% of the screen.

The graph display area covers the rest of the screen. In the screens that have graphics the information display area covers only 45% of the screen, and 35% of the space is used by the graph. The graph area is used to draw the graphs or to present the animation that accompanies the text.

THE SECTIONS

Each lesson is divided into 9 to 11 sections. Each section contains a set of screens with learning material, questions, and detailed solutions. Here is a general description of the main sections. The following three sections are present in every lesson.

The Prerequisites Section

This section contains the information that the student is supposed to know. The student is encouraged to review this section before he/she starts the core sections. This section is a review section and not part of the core material of the lesson. If the student has problems following this material, he/she is encouraged to go to the appropriate lesson or to get help from the teacher.

The Help Section

This section describes the basic use of the flow bar and the basic flow control elements like the pause. The purpose of this section is to familiarize the student with the flow, the graphs, and the animations that he/she will encounter in the core sections.

The Terms Section

It describes the key terms used in the core sections. This section can be reached from any screen in the core section, the practice problems section, and the progress check.

The Core Sections

Each lesson has a set of 4 to 6 core sections that contain the information that we want to relay to the student. Each section contains definitions, properties, examples and questions. The core sections of the first 9 lessons are given below.

PARABOLA

TYPES OF CONIC SECTIONS
PLOTTING A PARABOLA
COMPUTING STANDARD FORMS
FOCUS AND DIRECTRIX
PARABOLIC INEQUALITIES
X AND Y INTERCEPT

RELATIONS

RELATIONS AS SUBSETS
THE RELATION $G(X, Y) = 0$
THE RELATION $Y = F(X)$
COMMON FUNCTIONS

ELLIPSE

PLOTTING AN ELLIPSE
COMPUTING STANDARD FORMS
THE FOCI OF AN ELLIPSE
FINDING THE ELLIPSE

GRAPHS

REFLECTIONS
AXES OF SYMMETRY
REFLECTION ACROSS A POINT
TRANSLATIONS

CIRCLE

CIRCLE AS AN ELLIPSE
FINDING THE CIRCLE
COMPUTING STANDARD FORMS
AREA AND CIRCUMFERENCE

FUNCTIONS

DILATIONS
ABSOLUTE VALUE
COMPOSITION
REPEATED COMPOSITIONS

CONIC SECTIONS

HISTORY OF CONICS
PHYSICAL PROPERTIES
QUADRATIC EQUATIONS
QUADRATIC INEQUALITIES

POLYNOMIALS

OPERATIONS ON FUNCTIONS
DIVISION OF FUNCTIONS
FACTORING
POLYNOMIAL DIVISION

HYPERBOLA

PLOTTING A HYPERBOLA
COMPUTING STANDARD FORMS
FOCI AND ECCENTRICITY
FINDING THE HYPERBOLA

The Practice Problems Section

This section has a minimum of 50 practice problems, covering all core sections. These problems increase in difficulty to give the student confidence, motivation, and knowledge. When possible, the section contains some real-life problems so that the student can relate his/her knowledge to the real world.

The Progress Check Sections

This section has 20 problems, an evaluation screen, and several sets of remedial exercises. The 20 problems cover all core areas. The computer evaluates the student's answers. Then it displays an evaluation screen that presents the student's results. It points out the deficient areas and recommends the required set of remedial exercises for these areas. The student can print out the sets of remedial exercises and take them home. In this section, the flow is controlled by the system so that the evaluation is fair and consistent.

HARDWARE AND SOFTWARE

The system works on an IBM PC or an IBM compatible computer equipped with a color VGA monitor and a hard drive. We get good graphics and fast interaction when the lesson runs on a 286 system (or a better one like 386 and 486). The system requires 1 Meg of RAM, a mouse, and a hard drive with a minimum of 2.5 Meg of space for each installed lesson.

All necessary software except for the operating system (MS-DOS 3.1 or higher), is supplied by the system. Each lesson can be stored on one or two High Density 3.5 floppies. Each section of the lesson is stored as a binary file on the floppy. The floppy also contains an executable file, STUDENT.EXE and a text file that sets up the lesson environment [4].

The lessons run in the PC lab at F.I.U. on Zenith Data System Z-386SX PCS. These systems have VGA displays, 2 MG of RAM, mouse, printers, high density 3.5 floppies and run on MS-DOS 5.1.

THE TenCORE AUTHORIZING SYSTEM

The screens and the flow control are implemented under the TenCORE authoring multimedia system, version 6. TenCORE has 3 components, the TenCORE Producer, the TenCORE LAS, and the TenCORE CMIS [4].

TenCORE Producer is a part of a complete multimedia authoring system designed to aid in the implementation of CBI's. Producer's visually oriented design is helpful in the integration of text, line-drawing, and bit-mapped graphics with menus, questions, feedback, and conditional branching.

Other members of the TenCORE Authoring system used in this project are: TenCORE LAS (Language Authoring System) for sophisticated library modules and animations; and TenCORE CMIS (Computer Managed Instruction System) which, in conjunction with the producer, adds comprehensive learning management and record keeping features to any course.

ISD - Instructional System Development

One of the fundamental principles of instructional design is the separation of instructional process from content. There are general principles of learning that can be applied across content, so basic principles of instruction can be successfully applied regardless of content [2].

A specific set of such basic principles of instruction, obtained from the foundational theories, and grouped by either a conceptual or procedural model is called a Model of Instructional Design. Andrews and Goodson [1] have identified forty instructional design models in the literature. The one used by our project is the Instructional System Development model - ISD.

The ISD model is the best-known and most well-developed model for instructional design. Described in detail in [6,7], it is defined as a general system approach with multiple components called phases that are used to produce an instructional system. The phases are sequential sets of activities called analysis, design, development, implementation, and control. Its theoretical bases come from behavioral psychology, and its emphasis is on specifying behavioral objectives, analyzing learning tasks and activities, and teaching to specific levels of student performance.

ISD limitations

ISD has little to say regarding areas such as the nature of computer display and keyboards, the nature of immediate feedback available on computer, and programming the computer. Installing and maintaining the courseware is also away from the scope of ISD. ISD instructional methodology primarily involves presentation, practice, and testing, that relate to the three computerized methodologies that we described as tutorials, drills, and test.

The Instructional Computerized-System Design - ICSD

In the PRECALC project we have applied the learning model presented in Gagne [6]. The five phases for ISD described above are reduced to four in the ICSD. They are:

1. Front End Analysis: This phase includes the following traditional ISD steps:

- a) Perform needs analysis
- b) Conduct audience analysis
- c) Perform task analysis
- d) Perform learning environment analysis

In addition to the usual ISD steps, front end analysis includes some steps that are either modified or unique for the CBI medium

- e) Perform CBI course/media evaluation
- f) Conduct hardware/software selection, maintenance and security analysis
- g) Perform CMI system design

2. Design: For CBI, the purpose of the design phase is to identify the overall scope of the course. It include these common ISD steps:

- a) Develop Objectives
- b) Identify major course components
- c) Identify prerequisites
- d) Develop pre-test and post-tests

In addition to these steps, the design phase includes:

- e) System Design and detailed flowcharts

3. Development: After the design is complete, we begin the Development phase. For CBI, the purpose of the development phase is to create a detailed paper version of the

course, followed by a working version of the course on-line. The phases for CBI development are:

- a) Identify the contents of each CBI program component
- b) Transfer contents to storyboard forms to demonstrate, on paper, how CBI will look and execute
- c) Create the first on-line version of the course
- d) Develop supplemental course materials in other media, if needed
- e) Test and debug the on-line course
- f) Prepare the course for formative testing and evaluation

4. Evaluation: The formal Evaluation phase technically follows Development. However, the CBI evaluation measures should actually commence during the design and the development phases. These measures are critical to the success of the project, because CBI is often unmonitored. Therefore, CBI has to be extremely user-friendly and bug-free. The following are typical evaluation steps:

- a) Perform Formative (developmental) testing
- b) Conduct Summative evaluation

EVALUATION

We present the relationship between the students' learning styles (visual, auditory, and tactile/kinesthetic) and the improvement in their scores in precalculus. A more detailed analysis can be found in [5]. We used volunteers from the precalculus course offered at Florida International University from Spring, 1994 through Spring, 1995. Each volunteer went to the computer laboratory at Florida International University at the University Park campus, and went through at least one of the eight lessons of the PRECALC CBI System. At the beginning of each section, the student took a electronic test covering all sections of the lesson. The number of correct answers was recorded as the pre-evaluation. Then, the student went through the lesson. At the end of the lesson, the student took a electronic test. Again the number of correct answers was recorded as the post-evaluation. The student also filled out a questionnaire. We collected a sample of 139 evaluations. We used the SAS statistical package (Ver. 6.0) to analyze the data [8].

THE QUESTIONNAIRE

The evaluation, targeting learning styles, was conducted during the Fall of 1994 and the Spring of 1995. This questionnaire contains 47 questions divided into four sections.

Section 1 of the questionnaire contains 19 questions and focuses on the structural composition of the lesson and its impact on the user. This information will be used to improve

the presentation, the flow, and the friendliness of the program.

Section 2 has 10 questions and focuses on the emotional elements of the learner. It gives a personal view of the success (or failure) of the lesson.

Section 3 has 6 questions and gathers general information about the student. Information collected on this section includes: gender, computer experience, and other.

Section 4 contains 12 questions that identify the learning style of the student. The questions are part of a questionnaire created by Marie Carbo, Ph.D., to identify learning styles [3,5].

We use the overall mean of performance scores and the standard deviations to describe the data. The independent variable of interest in this research was the student's learning style. Three styles were considered: visual, auditory and tactile/kinesthetic. The dependent variables are the pre-evaluation, the post-evaluation, improvement (post-evaluation minus pre-evaluation) scores of the students, and the overall mean calculated as a composition of the answers from sections one and two of the questionnaire, reflecting the educational and perceptive context of the lessons as seen by the student.

The distribution of the sample among the different learning styles is: auditory students 18.7, tactile/kinesthetic 37.4% and visual learners 43.9%.

We found a wide acceptance of the system from the majority of the students. We pay special attention to question 2 section 2, where 73.4% of the students rated as above average the statement that the system helps them learn the material. Also, in question 19 section 1, 89.9% of the sample agree that the animation helped them understand the material. In question 17 section 1, 92.0% of the population agrees that the computer is a great learning tool. And in question 18 section 1, the sample agrees, in 92.8% of the cases, that the computer helps them retain the course material. On the down side, the lowest rated statements are "The PREREQUISITES were..." where 41% of the students rate it NOT HELPFUL, and "The question Feedback was..." where 35.5% of the students rate it NOT HELPFUL.

One-way analyses of variance were performed on the pre-evaluation score (based on number of correct answers out of 20), the improvement score, and overall mean by learning style. In this analysis, the pre-evaluation means differed by learning style with $p=0.002$, the improvement means differed by learning style with $p=0.0001$, and the overall mean differed by learning style with $p=0.0007$. These differences were collected from the information collected by the statistical analyses.

General Linear Model Procedure

Dependent variable : INITIAL SCORE $p = 0.0020$

Dependent variable : IMPROVEMENT $p = 0.0001$

Dependent variable : OVERALL MEAN $p = 0.0007$

| LEARNING STYLE | n | INITIAL SCORE | FINAL SCORE | IMPROV. |
|------------------------------|----------|----------------------|--------------------|----------------|
| VISUAL | 61 | 7.213 | 15.344 | 8.131 |
| TACTILE / KINESTHETIC | 52 | 9.365 | 15.288 | 5.923 |
| AUDITORY | 26 | 8.307 | 13.115 | 4.807 |

The Fisher's Least Significant Difference Test was used as the post hoc test. A 0.05 significance level was used, to identify any pairwise differences. In the analysis of the pre-evaluation scores, visual learners (m=7.21) scored lower than tactile/kinesthetic learners (m=9.37). No pairwise difference was noted between visual and auditory learners or between auditory and tactile/kinesthetic learners on the pre-evaluation score.

Pre-evaluation Means

| | | |
|--------|----------|---------------------|
| visual | auditory | tactile/kinesthetic |
| 7.21 | 8.31 | 9.37 |
| ----- | ----- | ----- |

In the analysis of the improvement scores, the visual learners (m=8.13) improved significantly more than either the auditory learners (m=4.81) or the tactile/kinesthetic learners (m=5.92). The auditory and tactile/kinesthetic learners did not differ on improvement means.

Improvement Means

| | | |
|----------|---------------------|--------|
| auditory | tactile/kinesthetic | visual |
| 4.81 | 5.92 | 8.13 |
| ----- | ----- | ----- |

In the analysis of the overall mean, the visual learners (m=3.83) gave a better approval score to the lessons than either the auditory learners (m=3.55) or the tactile/kinesthetic learners (m=3.61). The auditory and tactile/kinesthetic learners did not differ on overall means.

Overall Means

| | | |
|----------|---------------------|--------|
| auditory | tactile/kinesthetic | visual |
| 3.55 | 3.61 | 3.83 |

Overall there was significant improvement among all learning styles in the sample. Using the t-test on improvement mean scores, we show that all three learning styles means were significantly larger than zero ($p < 0.05$). In particular, the visual learners that started in the pre-evaluation with the lowest mean (7.213/20), finished with a post-evaluation mean (15.344/20) higher than the tactile/kinesthetic (15.288/20) and even higher than the auditory (13.115/20) students. In addition, visually motivated students had the highest improvement mean (8.131), followed by the tactile/kinesthetic with mean (5.923) and, finally, the auditory students, with the lowest improvement mean (4.807) in the study.

CONCLUSIONS

1. CBI in mathematics education: The use of the CBI PRECALC improves the student's knowledge and understanding of the material presented in the lessons.
2. CBI on student's attitudes: PRECALC increases the student's interest in mathematics.
3. Effect on the visual learners: There was a high improvement rate in the scores of visual learners. Students showed a high acceptance rate for the system. In addition, their written comments on the questionnaires showed their interest in continuing learning through CBI.
4. Effect on the tactile/kinesthetic learners: There was a significant improvement for the tactile/kinesthetic learners. They showed increased interest and motivation.
5. Effect on the auditory learners: There was a small, but significant improvement, with this group of students. Even though the system was not directed to these students, the practice and the visualization of the information helped them, though to a lower degree than the others, to learn the material.

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