Software Egineering e-learning Mathematical Software

Bekim Fetaji[1], Shefik Osmani[2] and Majlinda Fetaji[3]

***Abstract*—The research is proposing a new way of tackling the process of creation of e-learning interactive environments by integrating and undertaking the software engineering approach based on e-learning outcomes. The main research was focused towards creating an e-learning mathematical software solution that will be used in the course "Discrete Mathematics" to learn mathematical operation of different types such as system of linear equations, matrices, determinants, functions etc. This gives the student learners additional advantages in learning and solving equations, and perform matrix operations in a shorter time and have a visual representation of it. It is also an opportunity for the student learners to gain computational experience and to check their results with the software ones. In order to assess e-learning effectiveness we have proposed a methodology called ELUAT (E-learning Usability Attributes Testing) and as measuring instrument the PET (predefined evaluation tasks) inspection technique. It investigates and is modeled to support problem based learning.**

I. Introduction

The software solution developed has evolved as an idea to be a valuable tool for students and others who want to learn mathematical operation of different types such as system of linear equations, matrices, determinants, functions etc. Students complained about course learning content in "Discrete Mathematics" course which involves linear systems solution solving, finding the roots of a function, drawing and evaluating graphic of the function and other mathematical operations. Their opinion was that the learning content was not enough, and they spent to much time solving and calculating mathematical operations such as matrix and system operations with higher range. It means that they spent a lot of time in operations that are second hand and are simple calculations. Therefore we have initiated a research study to design and build software solution that will answer these requirements. The software was envisioned to provide and fulfill the next requirements:

System of linear equation – the software should be able to solve the system independent from the number of unknown variables in that system of equations.

Matrices – as an important part of these mathematical fields are matrices. The solutions of the systems of linear equations will be based on the solutions of the matrices.

The main operations that software will calculate are addition, multiplication, subtraction, inverse of a matrix, transposed matrix, finding their determinants, LU factorization and adjacent matrices.

Also, the software checks a few matrix properties such is it upper or lower, involuntary, orthogonal, symmetric, asymmetric and diagonal.

The software is able to solve determinants of any range by the same algorithm.

Root of the function – the users can also find the root of the nonlinear function by methods learned in the Numerical Analysis Course at SEEU. Those methods are Bisection, Secant, Newton-Raphson, Regula Falsi, Stephensen and Fixed Point.

Functions – the most challenging part of the developed software system is evaluating and drawing the graph given by a user in a text format. For these algorithms which are very hard to define we have used a Delphi package for evaluating the functions.

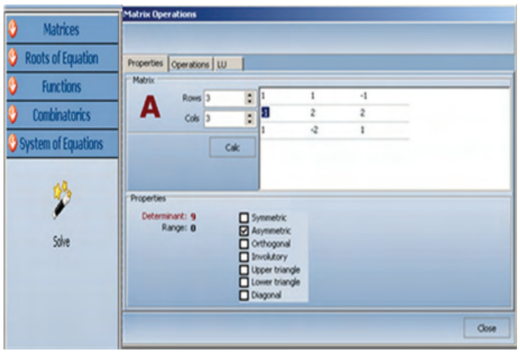

Fig. 1. The Interactive e-learning mathematical interface**.**

II. Research Methodology

We have considered the next learning modeling approaches:

1) the content-oriented,

2) the tool-oriented, or the

3) task-oriented approach [5].

We have decided to use the task-oriented approach. The data were collected throw usability testing, focus groups and interviews with prospective users. The purpose of the research realized is in order: (1) to gather information and asses e-learning interactions between human actors and the developed medium of instruction-the software solution, (intervention strategies and content), (2) determine the distance between learner activities and preconceived scenarios. The observed route of a learner has been used to give feedback information on the effective learning.

In our approach for the software solution we have decided to be modeled and used for Problem Based Learning. In Problem-Based Learning, students think, retrieve information for themselves, search for new ideas and apply them using the software solution.

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We have used the general principles and guidelines for HCI regarding the software design from [9], and general principles and guidelines for document design and guidelines for online documentation [3]. All this guidelines were closely advised and reviewed when designing the interactive e-learning mathematical tool. In order for the software solution to be successful it should be developed in close consultation and contacts and feedback with users. In the case of technology to support learning that means consulting with both teachers and learners. The matrix form contains three tabs: Properties, Operations and LU. The user can calculate the property of the matrix by following actions: (Note: The matrix should be a square matrix to perform these operations.)

Enter number of rows and columns in textboxes (the numbers should be positive):

1) On the grid enter the matrix values, 2) Click Calc button, 3) As the result users will get the determinant of the matrix, range and the properties in form of checkboxes. Check means that the matrix has that property.

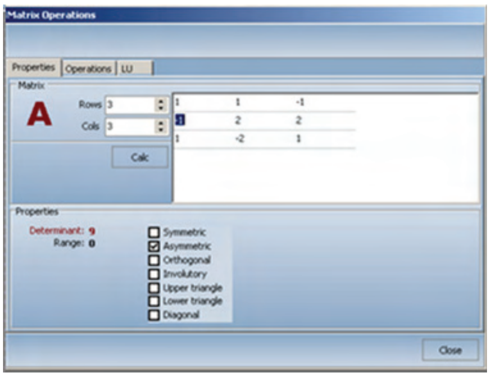

Fig 4. Properties tab of the Matrix Operations

In the operations tab users can calculate few matrix operations, as following: 1) Enter rows and columns of the first matrix, 2) On the grid below input values, 3) On the drop-down list select the action to perform, 4) If operation addition, subtraction or multiplication is selected the enter number of rows and columns of the second matrix the input the values, 5) Click on the Operate button

The result users will se in the result grid, depends on the action selected. In the screenshot there is an example of inverse of matrix.

In the following tab can be calculated the LU factorization as following: 1) As an input here you have one matrix, and output two matrices, 2) Input number of rows and columns of the matrix, 3) Input the values on the grid, 4) Click Factorize button. As a result users have two matrices Lower and Upper matrix (Figure 6.)

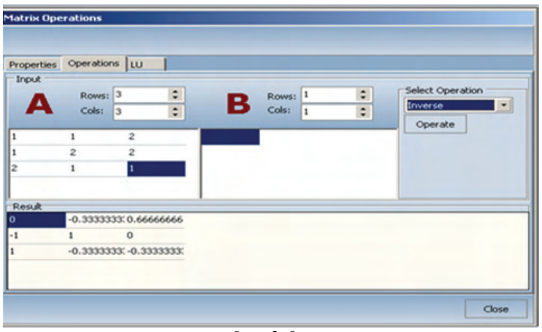

Fig 5. Operations tab of the Matrix Operations

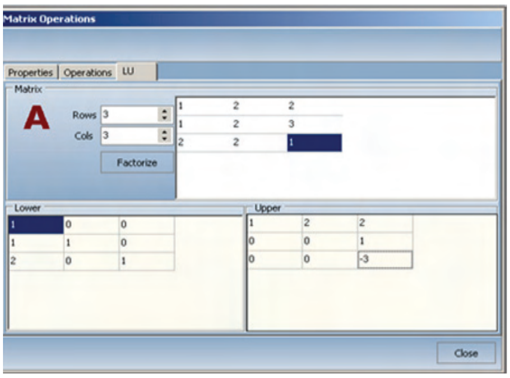

Fig 6. LU tab of the Matrix Operations

Roots of Equation - Bisection

To find the root of equation with method of Bisection users follows these steps: 1) In the f(x) textbox input the function, 2) Enter Tolerance, Endpoint A, Endpoint B and Steps, 3) Click Solve button. The result is displayed in the grid. To see the graph of this function user should click on the graph button (Figure 7).

III. Research Instrument Development

Major challenge for e-learning researchers is to assess e-learning effectiveness.

In order to do that we have proposed a methodology, called ELUAT (E-learning Usability Attributes Testing), which combines an inspection technique with user-testing based on 4 usability attributes we have set. The usability attributes we have set are: 1) Time to learn, 2) Performance speed; 3) Rate of errors; 4) Subjective satisfaction. The e-learning-methodology is necessary for presenting the e-learning in an efficient aspect.

The theoretical basis are pedagogical conceptions defined from [6]:

- Learning according to the constructivist perspective,
- usability of the e-learning environment and
- research about user opinions.

We have based the measuring instrument on the use of predefined evaluation tasks (PET), which precisely describe the activities to be performed during inspection in the form of a predefined tasks, measuring previously assessed usability attributes. We have named it as PET inspection technique and using this technique we evaluated usability attributes using evaluation tasks for a particular scenario. Evaluation tasks in this technique are determined throw designing several user scenarios and choosing the scenarios that include the most of the options of the software. This kind of approach using this technique has shown very effective, straightforward and useful in determining the distance between learner activities and preconceived scenarios in several research project we conducted. Using the ELUAT methodology and PET inspection technique we have gathered information on interactions between human actors (intervention strategies and content). Scenario contains at least a collection of components and a method. The components are roles, activities or activity-structures, which role does what (which activity) and at which moment is determined by the method which is made up of one or many plays formed by a series of acts. In an e-learning environment, information obtained from learner activity contain a certain pedagogical semantic. The observed route of a learner has been used to give feedback information on the level of learning and its effectiveness. We have considered the next learning modeling approaches: the content-oriented, the tool-oriented, and the task-oriented approach, and we have chosen the task oriented approach for which we developed the methodology to suite to our specifics.

Task n#	Time for:			M	S	E	R	O	H	F	*
	Task completion	Help search	Recover from errors								
		Time to Learn:		Total:							

Fig. 10. PET inspection technique task based form

The PET inspection technique uses the next measurements: M – Menu Error; R – Repeat task; F- Frustrations; S – Selection error; O – Uses online Help, E – Other errors, H - Help calls, *-Subjective Satisfaction (5-very high, 4-high, 3-average, 2-low, 1-very low).

This methodology and the inspection techniques has been used in several different research projects and it produced valuable information for the design of the subsequent studies and proved as viable methodology and technique.

IV. THE EXPERIMENT

The testing process is divided into three phases [5]: planning, acquisition and execution with evaluation. We have followed these guidelines. The planning phase provides an opportunity for the tester to determine what to test and how to test it. Users are asked to perform tasks while usability experts observe and take note of their actions. The acquisition phase is the time during which the required testing software is manufactured, data sets are defined and collected, and detailed test scripts are written. During the execution and evaluation phase the test scripts are executed and the results of that execution are evaluated to determine whether the product passed the test. The difficult areas that repeat themselves between multiple test participants reveal areas that should be studied and changed by the developers. User testing can often uncover very specific areas needing improvement, where focus groups and task analysis often find more general areas needing improvement. The major output of the planning phase is a set of detailed test plans. In a project that has functional requirements specified by use cases, a test plan should be written for each use case. There are a couple of advantages to this. Since many managers schedule development activity in terms of use cases, the functionality that becomes available for testing will be in use case increments. This facilitates determining which test plans should be utilized for a specific build pf the system. Second, this approach improves the traceability from the test cases back into the requirements model so that changes to the requirements can be matched by changes to the test cases. The specialist/analyst who sits in on the test will almost certainly be a behavioral psychologist, with cognitive psychology skills (the process of learning and understanding) and knowledge of HCI (Human Computer Interaction). They will also be a usability expert, but it's likely that their background will be in psychology rather than site design. When testing, psychology is far more important than the rational mechanics of good information architecture, though it's clearly desirable to understand both.

V. DATA COLLECTION AND RESULTS

According to the research of [8] for usability testing 5 users are enough, however we have used 10 users. After the usability test we had collected data from the 10 participants we had, were 5 of them were experts while the other 5 novices. In order to handle those data we have used the triangulation technique from [3], were we look at all data at the same time to see how the different data supports each other.

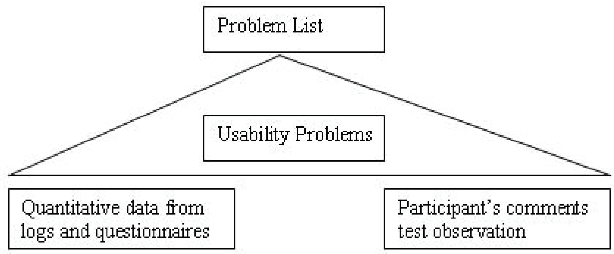

Fig. 4. Triangulation technique[3].

We also tabulated the data for the performance measurements using the next usability attributes: time to learn, speed of performance, rate of errors, Subjective satisfaction, and Frustration for the both classes of users Experts and novices. Please look at the appendix E for the tabulated data sheets and results. Here is the tabulated data sheet for time to learn, and speed of performance as well as the general usability requirements measures.

Usability Attribute	Measuring instrument	Value to be measured	Current Level average	Worst acceptable	Planned target level	Best possible
Time to learn	Task Scenario	Time to complete task	**134.7 s**	**200 s**	**120 s**	**90 s**
Speed of performance	Task Scenario	Time to complete task	**112 s**	**200 s**	**110 s**	**80 s**
Rate of errors	Task Scenario	Number of errors	**0.63**	**4**	**1**	**0**
Subjective satisfaction	Task Scenario	Satisfaction degree of users	**3.74**	**1**	**3**	**5**

* number. Subject satisfaction scale:
very high 5, high 4, average 3, low 2, very low 1

Table 1. Usability requirements for students

VI. CONCLUSION

The software solution as a new system solution is functioning practically and correctly as defined in its specifications. The experience introduced suggests the positive effects of using the interactive e-learning mathematical tool as our software solution. Randomly assigned treatment groups experienced and worked with the software solution.

Our conclusion regarding the first goal (1) to gather information and asses e-learning level and interactions between human actors and the developed medium of instruction - the software solution. Our analyses have shown that the e-learning interaction based on PET technique is quite high and the learning curve is quite high also. It is obvious that the student learner are faced with a lot of decisions and they need previous knowledge in order to use the software. The high learning curve of the system however is based on student interaction without any previous instructions. If the system is taught and instructed how to be used in classes then the learning curve might drop significantly and therefore the benefit of the usage of the system cold be much higher.

Our conclusion regarding the second goal (2) to determine the distance between learner activities and preconceived scenarios, our e-learning research analyses based on EULAT methodology and PET technique as well on focus group, we have seen, evidenced and concluded the next:

- The learners interpret their experiences according to their own perceptions and doing that they construct their own knowledge.
- Active construction demands a high level of independence and self organization.
- Construction of knowledge of the learners and the refinement of the ability to do so do not happen passively and autonomously.
- Learning is situated. The social, motivational and emotional contextual factors of the learning situation decisively control the ways and means of the learning- and retention-process as well as the use of the knowledge and abilities.

Students achieve better results and learn more when they can reflect what they learn. This is especially achieved using our developed software solution where they can reflect what they have learned previously, relate it to past experiences, and apply it practically using the software solution. Generally the software is very much appreciated and well welcomed.

The analysis of numerical methods is very important task in mathematics because it presents the general study of methods for solving complicated problems using the basic operations of arithmetic (addition, subtraction, multiplication, and division).

The contribution of this software solution is that uses a software approach for solving numerical problems that makes the job of the students taking the course “Numerical Analysis” easier as it gives them an opportunity to solve equations, and perform matrix operations in a very short time and learn more in depth and more thoroughly the different mathematical operations..

The speed or let we say the number of steps for finding solutions to equations with one variable will depend rapidly on the interval or the initial approximation points. If we choose closer approximation we will get faster and more accurate results. The reason why we can say that there is no “best” algorithm or there is no “best” method for every case, is just because some of the methods are faster but less accurate, and the others are slower but with a higher accuracy.

The software is easy to use, and is directed not only to students of computer science and mathematics, but to other users that want to perform different mathematical tasks included in the software or just want to test the results gained by hand.

The help file for using the software solution is another opportunity that simplifies the usage of the software as well as giving general information of each method used in its implementation, for those that have no or some knowledge about numerical analysis..

Since there is always room for improvement the study has to move with time, in the sense that it must be continuously improved in design and functionality in order to meet new demands imposed by new technology.

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