UNDERSTANDING THE NEED OF USING COMPUTER SIMULATORS FOR TEACHING MATHEMATICS TO ENGINEERING STUDENTS

Ikram E Khuda*, Muhammad Kashif Majeed, Zaheer Abbas Baloch, Umair Farooq
Faculty of Engineering Sciences and Technology, Iqra University, Karachi, Pakistan
*ikram@iqra.edu.pk

ABSTRACT— *Mathematics is taught both as a pure mathematics core course and also as part of other applied engineering domain courses, as electives. But learning helplessness in mathematics is of concern and importance in both. In many countries, mathematics is now taught along with simulation tools to help better understand and reduce the learning helplessness in the subject. But how significant is this approach for engineering students is still a research question. This paper is aimed to quantitatively assess this significance. For this purpose, an experimental research paradigm was setup, and Matlab was used as a learning simulation tool for Electrical Engineering students. This research explored that though computer-assisted tools are quite handy, but they are only of advantage in situations where practical implementation is to be done, however not when theoretical understanding is required. This research is then concluded with recommendations on the way of using computing tools in engineering subjects*

Keywords— Mathematics, Effective teaching, Learning helplessness, Electrical Engineering, Matlab.

I. INTRODUCTION

In addition to having its individual identity as a full-fledged graduate, master's, and doctorate level subject, mathematics is also taught as an integral part of many professional curriculums including engineering as a very important professional education. The design of an engineering program requires three types of mathematics studies [1]. First are those subjects which are pure and hardcore mathematics, for example, Calculus, Linear Algebra, Probability, Statistics, Complex variables, and Transforms, etc. Second are those subjects which are integrated with mathematics, for example, Signals and Systems, Electromagnetic Field Theory, Communication Systems, etc. Third, are those engineering courses which are totally applied but require that all previous mathematics-related courses have been covered. These include, for example, Signal Processing, Filter Designing, Digital Communication, Electronics Design, etc. Hence mathematics is an indispensable subject for engineers. However, it is pragmatic that the stated three different levels of mathematics learning must require different teaching pedagogies [2].

Recently with the boom of Information Communication Technology (ICT), many new teaching aids have been introduced to the teachers to make their lectures effective and more understandable to the students. Using computer software, particularly a simulator is one such example of ICT

usage [3-5]. Although these simulators appear to be very useful but sometimes they are used also in places where it is considered better to avoid them.

The purpose of this paper is to statistically understand and quantify the need of using computing software/ simulator for engineering students.

II. RESEARCH METHODOLOGY

In order to explore the impact of using a simulating tool(s) (as an ICT teaching aid) a research paradigm of two-way independent variable factorial ANOVA was designed to probe the following research questions:

i. To what degree use of a computer simulator was helpful in the learning of pure mathematics among the engineering students?
ii. To what degree use of a computer simulator was helpful in learning of technical engineering students?
iii. From (i) and (ii) is it is it convenient to state that a computer simulator could serve as an effective aid to eradicate learning helplessness of mathematics in engineering students?

To explore the answers for the above-stated questions samples of 360 undergraduate (average in studies) Electrical Engineering students were taken from Karachi, Pakistan. This sample was called as S. The experimental research was undertaken by testing S with different mathematical requirements. These requirements were categorized as $Calc$, SS, and FDT.

1) $Calc$ consisted of S tested for a pure mathematics subject taught to engineering students. The subject selected was Calculus.
2) SS consisted of S tested for an engineering subject involving both mathematics and engineering applications. The subject selected was Signals and Systems.
3) FDT consisted of S tested for engineering subject containing mathematics applied in developing engineering applications. The subject selected was Filter Design.

The second categorization of the test sample comprising of 360 students was made by teaching and testing them with three different ways of teaching. The first method involved the usage of no Matlab tool. Second type in-cooperated mixed use of the Matlab tool i.e. some portion of it was used and in third method, we made full use of Matlab as part of teaching pedagogy. In the analysis to follow the following abbreviations were used.

1) CU: Computer Usage
2) $Calc$: Calculus
3) SS: Signals and Systems
4) FDT: Filter Design Techniques
5) NMS: No use of Matlab Simulator
6) MMS: Mixed-use of Matlab Simulator
7) FMS: Full use of Matlab Simulator

This has formulated a research methodology comprising of a two-way independent variable factorial ANOVA design. Our sample S of 360 entries comprised of 120 for each type of Sample1, Sample 2, and Sample 3, and they were further categorized into 40 for NMS, 40 for MMS, and 40 for FMS. Hence there were two independent variables used.

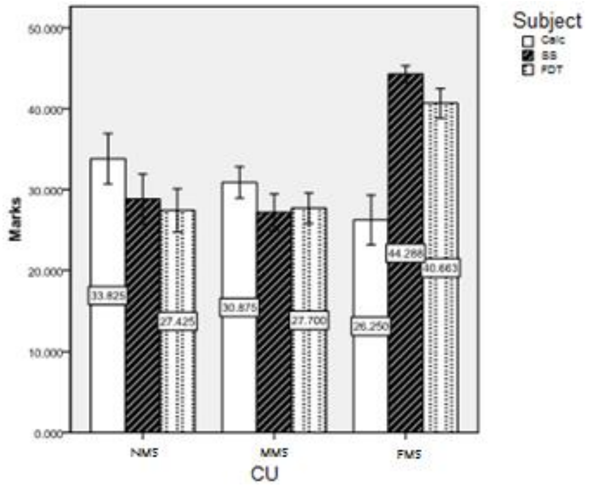

Figure 1: Bar chart plots

The first one was named *Subjects* which has three categories *Calc*, *SS, and FDT* and the second independent variable used was *CU* which also has three independent categories namely *NMS*, *MMS*, and *FMS*.

In order to carry out the experimental research, the whole course material was not used, however, selected topics from each of them were considered. The selection was made in such a way that common topics were acquired from *Calc*, *SS*, and *FDT* courses. For *Calc* topics selected was *Integration*. For *SS* topic selected was *Convolutional Integral*. For *FDT* topic selected was the design of *Analog Filters*.

A. Pedagogy of S1

Lecture and problem sets were taken from [6] for all the three cases of NMS, MMS, and FMS.

1) In *the NMS* approach, the problems of *Integrations* were taught theoretically.
2) In *the MMS* approach, the same problems as in $(A.1)$ were taught manually but graphs were plotted on Matlab.
3) In *the FMS* teaching method, a similar set of problems that were taught as in $(A.1)$ and $(A.2)$ were used, but only this time we used Matlab to determine the integration results.

B. Pedagogy of S2

Lecture and problem sets were taken from [6] for all the three cases of *NMS*, *MMS*, and *FMS*.

1) In *the NMS* method of teaching, time-domain convolution problems were solved. A conventional graphical and integral approach was used to obtain the results.
2) In *the MMS* method of teaching, the same problems as in $(B.1)$ were taught manually but the output signal was plotted on Matlab.
3) In *the FMS* method of teaching, again the similar set of problems were taught as in $(B.1)$ and $(B.2)$ but now Matlab was used for its built-in functions of $conv() * dt$ for continuous-time signals for finding convolution. Output response for each problem was also plotted on Matlab.

C. Pedagogy of S3

Lecture and problem sets were taken from [6] for all the three cases of *NMS*, *MMS*, and *FMS* in the design of *Analog Filters*.

1) In *the NMS* method of teaching, simple RC low pass and high pass filters were modeled and designed using the integral differential method.
2) In *the MMS* method of teaching, the same problems as in *(C.1)* were taught manually till the formulation of transfer function but magnitude and phase response behaviours were obtained on Matlab.
3) In the FMS
4) method of teaching, a similar set of problems were taught as in $(C.1)$ and $(C.2)$ but now Matlab built in *Filter Design and Analysis (FDA)* tool was used completely. The designed filter was 1^{st} order low pass and high pass *Butterworth* filter.

III. DATA ANALYSIS

The data collected for the 2-way independent ANOVA design paradigm was analyzed on SPSS® [7]. The data comprised of two independent variables. The first one was named *Subjects* which has three categories *Calc*, *SS, and FDT* and the second independent variable used was *CU* which also has three independent categories namely *NMS*, *MMS*, and *FMS*. Students in the sample were tested for the three subjects, Calculus, Signals and Systems and Filter Design Techniques with three levels of computer usage and results, i.e. the dependent variable used was *Marks*. As required in an independent ANOVA design paradigm, the independent variables are categorical and the dependent variable is continuous in type. In this study, the dependent variable *Marks* have the results stored as percentage values of the courses/ subject in *Subject* variable taught and tested against the three categories of *CU* variable.

The analysis was started by first finding the descriptive statistics. Results are shown in Table 1. A basic statistical analysis highlights the comparison of mean marks obtained by the students (in this experimental study). These are the marks obtained in *NMS*, *MMS* and *FMS* teaching pedagogies in the three samples of *Subjects.* In order to understand this better, bar chart plots are used as shown in Figure 1.

Table 1 Descriptive Statistics

Dependent Variable: Marks

Subjects	CU	Mean	Std. Deviation	N
Calc	NMS	33.82500	9.787191	40
	MMS	30.87500	6.110888	40
	FMS	26.25000	9.620358	40
	Total	30.31667	9.152291	120
SS	NMS	28.85000	9.617159	40
	MMS	27.20000	7.129570	40
	FMS	44.28750	3.265766	40
	Total	33.44583	10.497058	120
FDT	NMS	27.42500	8.320156	40
	MMS	27.70000	5.866900	40
	FMS	40.66250	5.770601	40
	Total	31.92917	9.129621	120
Total	NMS	30.03333	9.590728	120
	MMS	28.59167	6.545890	120
	FMS	37.06667	10.292759	120
	Total	31.89722	9.672448	360

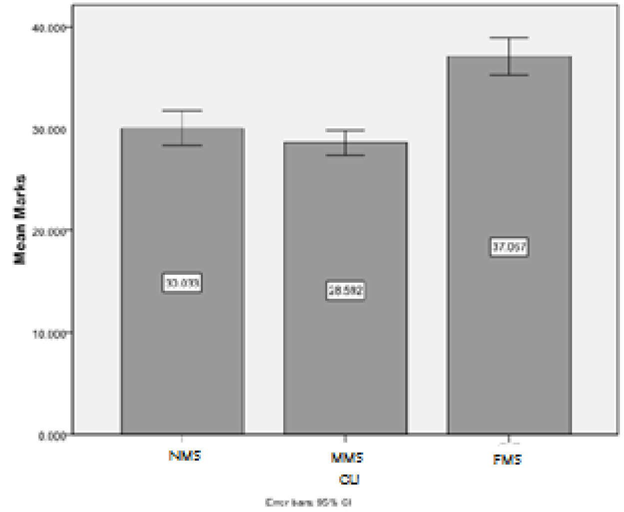

Figure 2: Bar chart of mean marks with different use of CA

A better comparison can also be made using contrast analysis. In particular, we have used Helmert contrasts, for of the advantages as mentioned in [8-10]. In this contrast, each category, except the last is compared to the mean effect of other categories. Table 2 shows the results of the Helmert Contrast on the *CU*.

Table 2 Contrasts Results

CU Helmert Contrast		Dependent Variable: Marks
Level 1 vs. Later	Contrast Estimate	-2.796
	Hypothesized Value	0
	Difference (Estimate - Hypothesized)	-2.796
	Std. Error	.847
	Sig.	.001
	95% Confidence Interval for Difference, Lower Bound	-4.462
	Upper Bound	-1.130
Level 2 vs. Level 3	Contrast Estimate	-8.475
	Hypothesized Value	0
	Difference (Estimate - Hypothesized)	-8.475
	Std. Error	.978
	Sig.	.000
	95% Confidence Interval for Difference, Lower Bound	-10.399
	Upper Bound	-6.551

As could be seen, in Table 2, Level 1 is the value when *FMS* was used. This is the reference value too. The top section in Table 2 shows the contrast of Level1 against the other two pedagogies, namely *NMS* and *FMS*. The obtained *p*-value of 0.001 at 95% CI suggested that this contrast is significant. The second (bottom) half of Table 2 showed the contrast/ comparison of Level 2 against Level 3, i.e. *MMS* vs. *NMS* approach. The *p*-value of 0.001 in Table 2 again suggested that this difference is also significant.

Analysis of Variance (ANOVA) test was also conducted and the results are shown in Table 3. This tells if any of the independent variables have produced an effect on the dependent variable. The effect of a variable taken in isolation is known as the *main effect*. The important things to look at in Table 3 are the *significant values* of the *independent variables*.

The main effect of $Subjects$ and CU both show an F ratio with a significant value. This means that the effect between each

subject (understudy) and CU is not by chance and hence cannot be ignored. Drawing the bar chart of marks obtained by the students in different subjects reveals a better meaning of these main effects. This is shown in Figures 2 and 3.

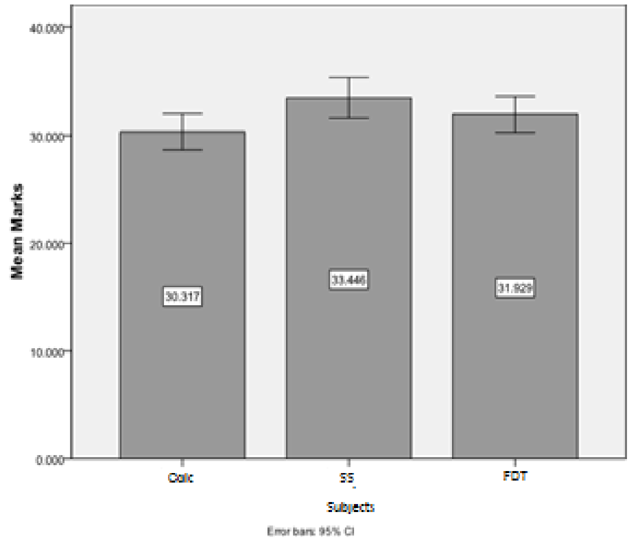

Figure 3 Bar Chart of Mean Marks in Different Subjects

Table 3 Factorial ANOVA Results for Main Effects and Interaction

Dependent Variable: Marks

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	13438.735[a]	8	1679.842	29.265	.000
Intercept	366275.803	1	366275.803	6380.933	.000
Subjects	587.685	2	293.842	5.119	.006
CU	4934.872	2	2467.436	42.985	.000
Subjects * CU	7916.178	4	1979.044	34.477	.000
Error	20147.962	351	57.402		
Total	399862.500	360			
Corrected Total	33586.697	359			

a. R Squared = .400 (Adjusted R Squared = .386)

Figure 2 has identified that the amount of computer usage has not significantly affected the marks obtained by the students as compared to NMS and MMS cases. But computer usage has significantly affected the total marks obtained by the students of FMS case against both NMS and MMS. This is regardless of subject, i.e. whichever subject is being studied. Reasonably bar graph of Figure 3 showed that no matter what level of CU was used, individual subjects have their own level of difficulty and learning requirements.

An important result in Table 3 is the interaction between $Subjects$ and CU. The F value is exceedingly significant. This means that the effect of the usage of CU is different for the different samples under study. This interaction is better viewed in the profile plots shown in Figure 4.

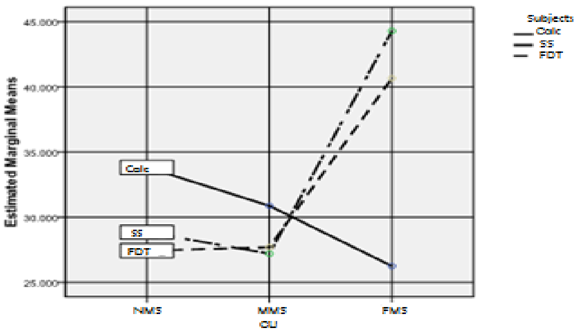

Figure 4: Profile Plots of Estimated Marginal Mean of Marks Scored

IV. DISCUSSION

This study has explored that using computer simulations have proved to be very useful for engineering students when teaching engineering subjects but not very productive in learning mathematics subjects. Results in Table 1 and plots in Figure 1 showed that with NMS and MMS modes of teaching, students displayed similar marks in the three subjects' groups. In FMS pedagogy, students displayed a higher gain in the marks. It is an interesting reflection that the use of the full CU. the method has not aided students to advance higher marks in their pure mathematics subject. Our understanding is this is because when solving pure math problems one needs to be firstly conceptually clear, then he/ she can expect to get assistance from the computer. The main ANOVA in Table 3 showed that subject under study cannot be overlooked. The bar chart in Figure 3 of marks obtained by the students in different subjects revealed the meaning of this main effect. The result of the usage of $the\ CU$ tool is unalike for the different samples under study. This is also shown in Figure 4. It is seen that for SS and FDT there is little change in marks when NMS and MMS mode was steered. However, there is a swift increase in the marks obtained by the students in these samples when FMS based examination was conducted. On the contrary usage of $the\ CU$ tool in $Calc$ has a significant decrease in the performance of the students. This result is in a match with the descriptive statistics of Table 1 and bar charts of Figure2 and 3 obtained earlier. Hence it can be stated that CU has produced a significant positive impact in engineering subjects, but not in the pure math subject.

V. CONCLUSION

This research study has explored that in the metropolitan hub of Pakistan, Karachi, Engineering students are still not making the most from computer application tools in learning mathematics. Though computer applications have proved successful in understanding engineering problems and applications, it has not shown its success in studying pure mathematics. Interestingly, the same students achieved better marks when they were tested to perform mathematics problems without computer tools. There are many probable reasons for this difference, but this is demonstrated that that though computer tools may be advantageous in better understanding of engineering subjects, but the equivalent cannot be applied to mathematics subjects for engineering students. So there should be a careful approach in the practice of computer tools into the engineering curriculum as a potential remedy for the failure of mathematical understanding in developing countries like Pakistan. To effectually use computer tools for mathematics and engineering subjects with the objective of removing the learned helplessness of students for mathematics there is an essential need to develop a new curriculum with the proper and as required inclusion of computer tools. Teacher training programs are required to be organized on a regular basis so that decent awareness of computer applications could be given to them and then they can better instruct it in their lectures and notes.

REFERENCES

[1] Cardella, M. E. (2008). Which mathematics should we teach engineering Students? An empirically grounded case for a broad notion of mathematical thinking. *Teaching Mathematics and Its Applications: International Journal of the IMA*, *27*(3), 150-159.

[2] Khuda, I. E., Naqvi, H. A., & Siddiqui, A. A. (2019, December). Improved Teaching Pedagogy for Convolution of Continuous Time Signals. In *2019 4th International Conference on Emerging Trends in Engineering, Sciences and Technology (ICEEST)* (pp. 1-6). IEEE.

[3] Prasad, P. W. C., Alsadoon, A., Beg, A., & Chan, A. (2016). Using simulators for teaching computer organization and architecture. *Computer Applications in Engineering Education*, *24*(2), 215-224.

[4] Karal, H., Çebi, A., & Pekşen, M. (2010). The web based simulation proposal to 8th grade primary school students' difficulties in problem solving. *Procedia-Social and Behavioral Sciences*, *2*(2), 4540-4545.

[5] Sturm BL, Gibson JD. Signals and Systems using MATLAB: an integrated suite of applications for exploring and teaching media signal processing. Frontiers in Education, 2005. FIE'05. Proceedings 35th Annual Conference 2005. IEEE.

[6] Hsu, H. P., & Hsu, H. P. (2014). *Signals and systems* (Vol. 8). New York: McGraw-Hill Education.

[7] Green, S. B., & Salkind, N. J. (2016). *Using SPSS for Windows and Macintosh, books a la carte*. Pearson.

[8] Laird, A. R., Fox, P. M., Price, C. J., Glahn, D. C., Uecker, A. M., Lancaster, J. L., ... & Fox, P. T. (2005). ALE meta-analysis: Controlling the false discovery rate and performing statistical contrasts. *Human brain mapping*, *25*(1), 155-164.

[9] Fang, S., Li, J., Tian, Y., Huang, T., & Chen, X. (2016). Learning discriminative subspaces on random contrasts for image saliency analysis. *IEEE transactions on neural networks and learning systems*, *28*(5), 1095-1108.

[10] Marino, M. A., Pinker, K., Leithner, D., Sung, J., Avendano, D., Morris,E. A., & Jochelson, M. (2020). Contrast-enhanced mammography and radiomics analysis for noninvasive breast cancer characterization: initial results. *Molecular imaging and biology*, *22*(3), 780-787.