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Statistical Evaluation of Computer Usage En Route to Effective Teaching for Undergraduate Engineering Students: Case Study from Pakistan

Ikram E Khuda

Assistant Professor Faculty of Engineering Sciences and Technology, Iqra University, Main Campus, Karachi, Pakistan

Abstract

Mathematics is an indispensible part of engineering discipline. Studies show that in engineering students the learned helplessness for math is of high proportion. To confront this issue, as practiced in developed countries, computer based simulations have been in-cooperated in the curriculum of Electrical Engineering by the Higher Education Commission (HEC) in Pakistan. In this research a quantitative analysis has been made to determine the effectiveness of computer assisted learning in pure math and applied math/ pure engineering subjects for engineering students. Research instrument used for this purpose is computer software Matlab. Findings showed increase in marks when computer was used in engineering subjects but decrease in grades in the study of pure math subjects. This has suggested the idea that though computer assisted tools may be beneficial in engineering subjects where major concern is implementation not the mathematical details involved in them but the same cannot be applied for theoretical math subjects where the need of concept building is more essential than the implementations. So there should be caution in usage of computer tools into engineering curriculum as a potential remedy to wipe out mathematical learned helplessness. The results are followed by conclusions for a more pragmatic way of computer usage in the engineering curriculum.

Keywords: Engineering discipline, computer based simulations, Electrical Engineering, learned helplessness, mathematics, and curriculum.

1. Introduction

Engineering subjects can be broadly characterized as, (1) pure math subjects, (2) subjects containing both math working and engineering knowledge and (3) pure technical or applied math subjects which do require math background but do not involve detail math working. One way or the other, engineering students have to deal with mathematics both as a theoretical subject and second as its conceptual understanding in terms of engineering applications. Although mathematics is unavoidable from the engineering community, but at the same time it is important that the depth of its study should not be interfering with a wider focus on practical applications in engineering discipline. It is a very common observation of instructors that most of the engineering students find their studies too mathematical which makes the students uncomfortable and raises anxiety and learned helplessness for math.

In this discussion, computer application softwares have played an important role to facilitate both instructors and students. Hypothetically the software packages are assumed to efficiently connect the abstract world of mathematics with the physical world of engineering. Their purpose is to simulate engineering problems to help students get a quicker understanding with clearer concepts to solve them. The question is that whether students who are using these softwares are also efficient in mathematical details which the softwares do for us? Are students using such softwares for granted and conceptually they are still unaware of the required math knowledge?

In developed counties computer aided learning has been used as an important solution for developing better understanding of mathematics both in general and particular to engineering studies [1-12]. But this fact must also be considered that in those countries where computers have been used in schools for many years, and for which there are decades of research into them, targeted to individual subject and its curriculum. It is therefore questionable whether all the findings outlined for developed countries will be equally and efficiently transferable to developing nations like Pakistan where majority of the students first get in interaction with computers for study purpose after their high school!

Some particular researches which have been conducted in other developing countries have shown mixed results about the impact of computer assisted learning in academics and particular to mathematics. A Turkish study in [13] accounted that usage of dynamic geometry software did not bring any distinguishable improvement in the learning capabilities of the students. There was no statistically significant impact of computer use. Agyei et al. in [14] made a similar research in Ghana. Accordingly the key factors in failure of computer assisted education are firstly the lack from administration support and secondly ICT infrastructure unavailability. Critical in this finding was teachers finding insufficient time to integrate computer simulations in their course plan. In India a study on computer–assisted learning (CAL) was carried out in [15] for two years. The research comprised of approximately 15 000 students in the city of Vadodara. Results were quite positive and showed that the CAL was quite successful and had a considerable and statistically momentous effect on mathematics learning achievements from first year to second year of research study. In South Africa the Khanya Project was established in 2002 and super-headed by the Western Cape Education Department (WCED) of the province. Its objectives were to work in urban and rural schools in the Western Cape province and provide them with well equipped computer laboratories using MasterMaths in helping students in their math related problems. A South African study in [16] researched that that there was not a very clear picture for the usefulness of the Khanya Project. According to them, the computer alone cannot impact on the mathematical attainment of a student. The way computers are in-cooperated in the curriculum is a very crucial factor to understand how they can potentially be advantageous or give a positive impact. For Pakistan, impact of ICT and computer assisted tools has been studied at school level to some extent by researchers in [17-21].

So far no conclusive or detailed research has been conducted and published at graduate level of professional studies like engineering, medicine, business or media sciences for removing learning helplessness of math in these individual disciplines particular to the region under study. Considering its importance, we have carried out a research in the form of a case study to find out the impact of computer assisted tool in the learning and understanding of pure math and applied engineering subjects with the concern that to what extent learning helplessness of math is being reduced. The computer tool selected was Matlab.

2. Research Design and Methodology

2.1 Research Questions

The objective was to determine impact of computer assisted study for removing learning helplessness for math in engineering. Computer application tool Matlab was used as the research instrument. The results of this impact were reproduced in the marks obtained by the students in the tests conducted, particularly for this study. The following research questions were investigated:

i. To what extent computer application tool was effective in the learning of pure mathematics among the students of engineering?
ii. To what extent computer application tool was effective in learning of technical subjects among the students of engineering?
iii. From (i) and (ii) is it possible to generalize that computer application tools could serve as a useful resource to finish off learning helplessness of engineering students? If Yes, how? If No, why not?

2.2 Participant's Profile and Design Type

The case study was conducted on undergraduate engineering students with the objective to answer the research questions stated above by learning the impact of computer usage in pure math and applied engineering subjects (involving math principles). For this purpose a random sample of 360 male and female Engineering students were taken. Since in the region of study, ratio of male to female students studying Engineering is not equally comparable; with males in much higher number than females therefore sample categorization was not made on the basis of gender. These students were all of the age between 18 and 21. All were randomly selected from the population of those Engineering students who had an average math background. All these students had the origin from Pakistan with English as their second language. They were all urbanely located from the metropolitan Karachi. No foreigners or Cambridge level students were considered in this study. This sample of 360 students was named "S". The experimental research was undertaken by categorizing "S" with two independent variables (1) Subject and (2) CA. CA is for Computer Application. In the Subject category following three types were used:

1) Sample_1 consisted of S tested for a pure math subject taught in Engineering. Subject selected was Complex Variables and Transforms (CVT).
2) Sample_2 consisted of S tested for an engineering subject involving both math and engineering applications. The subject selected was Signals and Systems (SnS).
3) Sample_3 consisted of S tested for engineering subject characterizing applied math and engineering applications. The subject selected was Filter Design (FD).

The next stage of categorization of "S" was made on each Sample_1, Sample_2 and Sample_3 with three different ways of teaching and testing using Compute Application tool Matlab. The first method involved usage of no Matlab tool (NMT), second type in cooperated mixed use of Matlab tool (MMT) i.e. some portion of it was used and in the third method full use of Matlab (FMT) as part of teaching pedagogy was utilized.

The two stages of characterization on two independent variables have made a design type of two-way independent variable factorial analysis of variance (ANOVA) . The random sample "S" of 360 entries comprised of 120 for each type of testing Sample_1,Sample_2 and Sample_3. The 120 in each testing sample were divided into 40 for NMT, 40 for MMT and 40 for FMT.

2.3 Research Methodology

In order to conduct this research, the whole course material was not taken but rather selected topics from each of them were used. The selection was made in such a way that the similar topics were acquired from CVT, SnS and FD subjects. For Sample_1, topics selected were Laplace and Fourier Transforms. For Sample_2, topic selected was Response of LTI Systems, i.e. Convolution in time domain. Similarly for Sample_3, topic selected was design of FIR filters.

2.3.1 Pedagogy of Sample_1:

Lecture and problem set was taken from [21, 22] for all the three cases of NMT, MMT and FMT.

1) In NMT method of teaching, all the problems of Laplace and Fourier transforms were done theoretically. Graphs were also plotted manually.
2) In MMT method of teaching, the same problems as in (1) were taught manually but graphs for magnitude and phase spectra were plotted on Matlab.
3) In FMT method of teaching, again the similar set of problems were taught as in (1) and (2) but now Matlab built in functions of *Laplace, TF( ) , FFT( ),abs( )* and *Angle( )* were used to determine Laplace, transfer function, Fourier, magnitude and phase spectra respectively of the signals.

2.3.2 Pedagogy of Sample_2:

Lecture and problem set was taken from [23] for all the three cases of NMT, MMT and FMT.

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

2.3.3 Pedagogy of Sample_3:

Lecture and problem set was taken from [24] for all the three cases of NMT, MMT and FMT for the design of digital FIR filters

1) In NMT method of teaching, FIR we started with desired magnitude response with zero phase applied DTFT and then truncated it by multiplying it with appropriate windowing function. Windowing techniques was used and different windows were used to formulate the FIR filter system.
2) In MMT method of teaching, the same problems as in (1) were taught manually till the formulation of transfer function but multiplication with windows and making the system causal were done using Matlab.
3) In FMT method of teaching, again the similar set of problems were taught as in (1) and (2) but now Matlab built in *Filter Design and Analysis (FDA)* tool was used completely to determine the impulse response and transfer function of the desired FIR filter.

3. Results of Quantitative Data Analysis

Quantitative data analysis of two way independent, factorial ANOVA was performed using SPSS®. The data comprised of two independent variables; (1) **Subject** and (2) **CA** and one dependent variable termed as **Marks**. The independent variables were categorical and the dependent variable is continuous in nature. The independent variable Subject has 3 categories, **Sample_1**, **Sample_2** and **Sample_3**. The independent variable **CA** also has three categories, **NMT**, **MMT** and **FMT**. The dependent variable Marks contained percentage results of the students in the Subject variable taught and then tested using the three categories of CA variable.

At first descriptive statistics test in Table 1 was performed. This showed a comparison of means marks obtained by the students with NMT, MMT and FMT in the three samples. A better interpretation of this descriptive statistics can be made from bar chart plots of Figure1.

Dependent Variable:Marks

Subject	CA	Mean	Std. Deviation	N
Sample_1	NMT	33.82500	9.787191	40
	MMT	30.87500	6.110888	40
	FMT	26.25000	9.620358	40
	Total	30.31667	9.152291	120
Sample_2	NMT	28.85000	9.617159	40
	MMT	27.20000	7.129570	40
	FMT	44.28750	3.265766	40
	Total	33.44583	10.497058	120
Sample_3	NMT	27.42500	8.320156	40
	MMT	27.70000	5.866900	40
	FMT	40.66250	5.770601	40
	Total	31.92917	9.129621	120
Total	NMT	30.03333	9.590728	120
	MMT	28.59167	6.545890	120
	FMT	37.06667	10.292759	120
	Total	31.89722	9.672448	360

Table 1 Descriptive Statistics

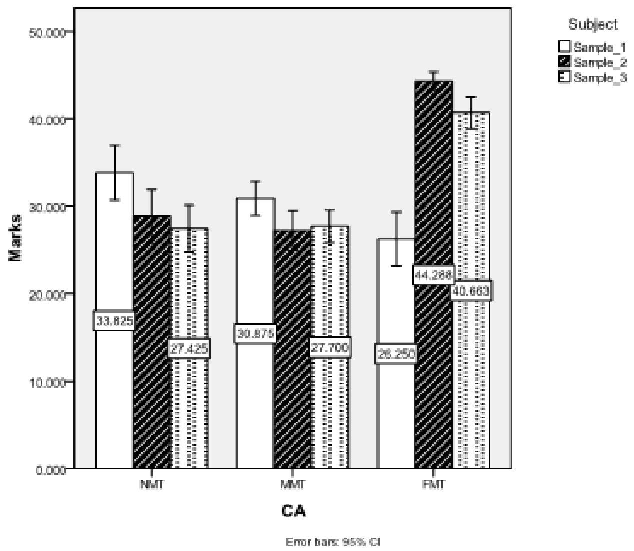


Figure 1 Bar Chart of Mean Marks in different Samples and Different Use of CA Tool

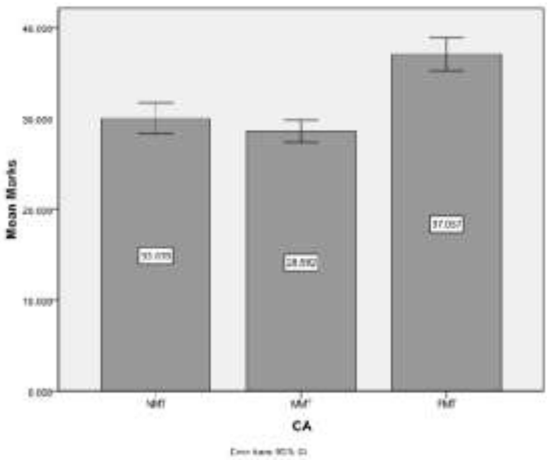
Next we analyzed the main ANOVA shown in Table 2. This is the most important part of the output because it showed whether any of the independent variables had an effect on the dependent variable. The effect of a variable taken in isolation is known as the main effect. The important results in Table 2 are the significant values of the independent variables obtained from the F statistics. Main effect of Subject and CA both show F ratio with a significant value. This meant that individual effect of subject (under study) and likewise of CA cannot be ignored. Plotting the bar chart of marks obtained by the students in different subjects also revealed similar meaning of these main effects. This is shown in Figure 2 and Figure 3. The former indicated that the amount of computer techniques used significantly affected on the total marks obtained by the students. This is irrespective of subjects' effect, i.e. whatever subject is being studied. Comparatively bar graph of Figure 3 showed that no matter what level of CA was used, individual subjects have their own level of difficulty and learning requirements.

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
Subject	587.685	2	293.842	5.119	.006
CA	4934.872	2	2467.436	42.985	.000
Subject * CA	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)

Table 2 Factorial ANOVA Results for Main Effects and Interaction



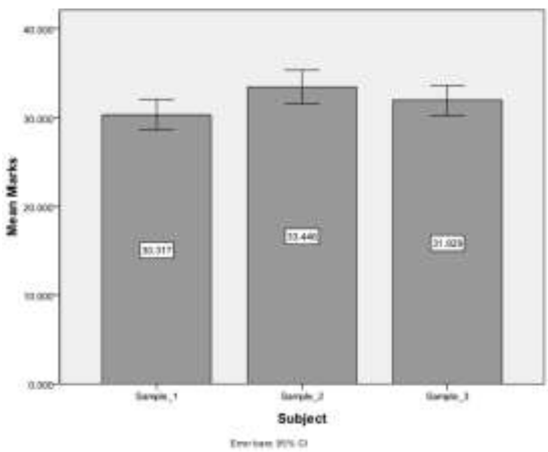


Figure 2 Bar Chart of Mean Marks with Different Use of CA Tool

Figure 3 Bar Chart of Mean Marks in Different Subjects

Another very important result in Table 2 is the interaction between Subject and CA. The F value of this test is highly significant. This meant that effect of the usage of CA is different for the different samples under study. This interaction is better interpretable from the profile plots shown in Figure 4.

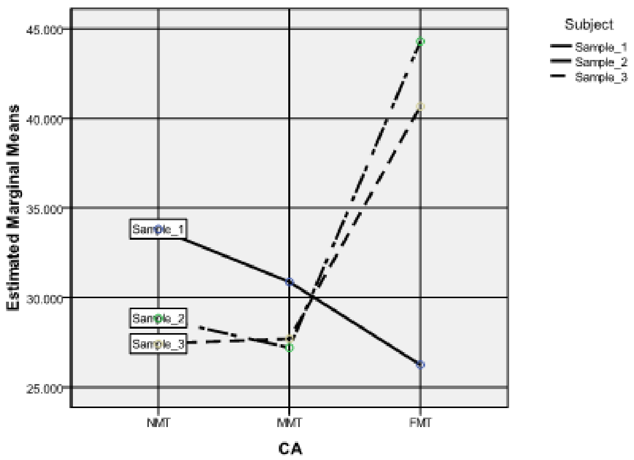


Figure 4 Profile Plots of Estimated Marginal Mean of Marks Scored

In statistical inference omega squared (ω^2) is an approximation of the dependent variance accounted for by the independent variable in the population for a fixed effects model. This parameter is commonly used to determine the effect size of each of independent variables [25]. This effect size estimate is based on the sum of squares and uses the variance explained by the model and the error variance. For calculating the effect size it is firstly required to compute a variance component for each of the effects (comprising the two main effects and the interaction) and then use it to calculate the effect sizes of each. Let the first main effect is termed "A", the second main effect "B" and the interaction effect "A × B" then the variance component for each of these is based on the mean squares of each effect and the sample sizes on which they were based upon, as shown in Eq (1), (2) and (3).

$$\hat{\sigma}^2_\alpha = \frac{(a-1)(MS_A - MS_R)}{nab} \qquad (1)$$

$$\hat{\sigma}^2_\beta = \frac{(b-1)(MS_B - MS_R)}{nab} \qquad (2)$$

$$\hat{\sigma}^2_{\alpha\beta} = \frac{(a-1)(b-1)(MS_{A\times B} - MS_R)}{nab} \qquad (3)$$

In these equations, "*a"* is the number of levels of the first independent variable, "*b"* is the number of levels of the second independent variable and *n* is the number per condition. The parameters required in Eq(1), Eq(2) and Eq(3) can be obtained easily from Table 2.

The first independent variable and main effect was Subject. This had 3 levels and had a mean square of 293.842. Second independent variable was CA which also had 3 levels with a mean square value of

2467.436**.** For the case of interaction the mean square value was 1979.044. The number of students in each sample was 40. The residual mean square is 57.402. By substituting all these values, Eq (1), (2) and (3) became as,

$$\hat{\sigma}_{\alpha}^{2} = \frac{(3-1)(293.842-57.402)}{(40\times 3\times 3)} = 1.3136$$

$$\hat{\sigma}_{\beta}^{2} = \frac{(3-1)(2467.436-57.402)}{(40\times 3\times 3)} = 13.3891$$

$$\hat{\sigma}_{\alpha\beta}^{2} = \frac{(3-1)(3-1)(1979.044-57.402)}{(40\times 3\times 3)} = 10.6758$$

Total variability which is the sum of these variances and the residual mean squares is as,

$$\hat{\boldsymbol{\sigma}}_{\boldsymbol{total}}^{2} = \hat{\boldsymbol{\sigma}}_{\boldsymbol{\alpha}}^{2} + \hat{\boldsymbol{\sigma}}_{\boldsymbol{\beta}}^{2} + \hat{\boldsymbol{\sigma}}_{\boldsymbol{\alpha\beta}}^{2} + \boldsymbol{MS_R} \qquad (4)$$

$$\hat{\sigma}_{total}^{2} = 1.3136 + 13.3891 + 10.6758 + 1.4993 + 57.402$$
$$\hat{\sigma}_{total}^{2} = 84.2798$$

After calculating the total variability, the effect size is simply the variance estimate for the effect which is required divided by the total variance estimate.

$$\boldsymbol{\omega}_{\boldsymbol{effect}}^{2} = \frac{\hat{\boldsymbol{\sigma}}_{\boldsymbol{effect}}^{2}}{\hat{\boldsymbol{\sigma}}_{\boldsymbol{total}}^{2}} \qquad (5)$$

Main Effect of Subject:

$$\omega_{subject}^{2} = \frac{\hat{\sigma}_{subject}^{2}}{\hat{\sigma}_{total}^{2}} = \frac{1.3136}{84.2798} = 0.0156$$

Main Effect of CA:

$$\omega_{CA}^{2} = \frac{\hat{\sigma}_{CA}^{2}}{\hat{\sigma}_{total}^{2}} = \frac{13.3891}{84.2798} = 0.1589$$

Interaction of Subject and ICT:

$$\omega_{Subject\times CA}^{2} = \frac{\hat{\sigma}_{Subject\times CA}^{2}}{\hat{\sigma}_{total}^{2}} = \frac{10.6758}{84.2798} = 0.1267$$

For making these values comparable to correlation coefficient “r”, square root of ω^2 for each case, Subject, CA and interaction of them was taken to give effect size in terms of correlation coefficient as 0.1259 (12.59%) for subject, effect size of 0.3986 (39.86%) for CA and an effect size of 0.3559 (35.59%) for the interaction.

4. Discussion on the Results with Answers to the Research Questions

In response to the first two research questions, our results showed that computer application tool Matlab has proved to be a very useful for engineering students when teaching engineering subjects but not very fruitful in teaching math subjects to engineers explicitly. Results in the Table 1 and bar chart plots in Figure1 showed that with NMT and MMT approach, students showed almost similar marks in the three subjects' categories. Using an approach involving fully computer based pedagogy (FMT), students showed a higher gain in the marks in pure technical and no math working involvement. However this is interesting observation that use of full CA method has not helped students to gain higher marks in their pure math subject. In fact students' marks are lesser in NMT and MMT based exam in the Sample_1 or pure math category. This could be either due to weaker teaching technique of using Matlab in solving math problems or it could be because when solving pure math problems one needs to be firstly conceptually clear then he/ she can expect to get assistance from the computer. In the first case proper care was taken to teach students with the tool Matlab. So assuming that there was no problem in that case, it appeared that students must have spent more time in learning Matlab then to learn the math subject properly and consequently could not reach to understanding the problem.

The main ANOVA in Table 2 was performed to find the main effects of the subjects. It showed that subject under study cannot be ignored. Drawing the bar chart of marks obtained by the students in different subjects in Figure 3 revealed the meaning of this main effect. Result of the usage of CA tool Matlab is different for the different samples under study. This interaction is better interpretable by the profile plots shown in Figure 4. This clearly showed that for Sample_2 and Sample_3 there is little change in marks when NMT and MMT mode was conducted. However there is a rapid increase in the marks obtained by the students in these samples when FMT based tests were conducted. On the contrary, usage of CA tool Matlab in Sample_1 has a steady decrease in the performance of the students with the use of it. This result is in match with the descriptive statistics of Table 1 and bar charts of Figure 2 and 3 obtained earlier. In short it can be stated with good confidence that CA tool Matlab has produced positive impact in engineering subjects but not very appreciative in pure math subject. However main effects of Figure 2 and Figure 3 showed that both independent variables effected on the marks gained by the students but interaction and profile plot of Figure 4 further elaborated our understanding that CA tool Matlab has effected positively only in engineering subjects but not in pure math subject. Effect size calculations (shown in the preceding section) showed that the effect was 12.59% for the dependent variable subject, effect size of CA tool usage was 39.86% and an effect size of 35.59 for the interaction between the two. These high values of effect sizes have made the independent dependent variables substantive for the quantitative analysis. This meant that CA tool Matlab has not been very much successful as an alternative to make engineering students understand the mathematical concepts which are very much necessary in learning and understanding math. But when applications are concerned CA tool can be used to increase the speed of solving the math problems without actually doing it!

Considering the current situation, it is difficult to comment on the third question that if CA tool Matlab is serving the role of bridging the gap between math and engineering or if that could be generalized for any other computer application tool. For generalization it is required to carry out more extensive exercise including more subjects, more tools and increasing the sample size. This could be observed from the results that CA tools do help in solving mathematical problems in engineering courses by using clear simulations but they are not very good in digging deep inside the problem to answer the basic question of ***why*** in a pure mathematical problem. By *why* it is meant that in a problem scenario the solution provider has to know as *why a particular method is being chosen for solving the problem.* In contrast normally in engineering situations the solution provider has to deal with the ***how***, i.e. (once the solution method is known) only needs to be aware of as to how to use the method to solve the problem.

5. CONCLUSIONS

The findings in this case study has revealed that in the metropolitan hub of Pakistan, Karachi, Engineering students are still not making the most from computer application tools in learning math. However computer applications have been quite useful in understanding engineering problems and developing real time applications but the same is not true when studying math alone. Interestingly the same students achieved better marks when they were tested to perform math problems without using such tools. There could be many possible reasons for this disparity, but this is proven that that though computer tools may be beneficial in better understanding of engineering subjects but the same cannot be applied for math subjects. So there should be caution in usage of computer tools into engineering curriculum as a potential panacea for mathematical failure in developing countries like Pakistan. To effectively use them for math and engineering subjects with a goal of reducing the gap in between the two subjects as well as removing learned helplessness of students for math there is a dire need to develop a new and effective teaching methodology. Work is needed to find out the potential factors which are causing the hindrance for not getting good results from it. Teacher training programs need to be organized on regular basis so that good awareness computer applications could be given to them and then they can better inculcate it in their lectures and notes.

Similar studies should be conducted in other parts of the country and this could be extended into a cohort and cross sectional research to better compare the situations and results so that the goal of better understanding and learning of math and engineering for engineering students could be achieved. As indicated in [26] plans like “Action Research” could be quite useful in improving effective teaching for the undergraduate engineering students. The objective is to bring correlation between the course material and the students’ mental capacities without losing the aims and scopes of the subject. This would lead to cultivate result oriented activities and make math interesting to the engineering students; all this which might be little difficult by using computer softwares alone. Similarly as noted in [27], instructing students in a way to mentor and nurture their analytical skills and not just usage of softwares can surly produce effective professionals for the future. Accordingly it is more important to occupy students with knowledge dissemination then just providing them knowledge.

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