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Effect of Computer Learning on performance in early Architecture Education

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Abstract: A mixed cohort of students with different experience backgrounds join the architecture degree. While some are well familiar with the user interface of computer and 3-D digital tools, others are not. The effect of such prior knowledge and their corresponding digital and analog performance in a designed experiment was evaluated with a sample of 38 first-year students. This was done to understand the performance effects of previous computer learning in students. Computer learning of the sample was studied in terms of years of computer exposure, the number of software known, and knowledge of 3D software or SketchUp. The results suggest that none of the factors contributed to the digital performance of students. This provided suggestions regarding the computer teaching emphasis which should be placed on students having less computer learning.

Keywords: Architecture Education; Sketching; Digital tools; digital performance; intuitive interface; Mental Imagery.

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1. Introduction

The effect of technology on design education has led to an irreversible change that continues to grow stronger with time. The presence and acceptance of digital tools in design detailing, modelling, visualizing, and conception has become common practice to the extent that students lacking in either hardware or software requirements find themselves out of place in architecture studios. Such importance in the studio was earlier attributed to students having good sketching skills. The demand for software proficiency is even greater in the case of professional practice leading to students prioritizing the learning of tools as 3D max, Revit, Rhinoceros, especially towards the end of their degree. Earlier digital learning was a specific requirement of bachelor education which was fulfilled by dedicated software learning lectures. In times when the use and presence of computing systems were rare the college used to provide infrastructure to students through dedicated CAD labs and printing facilities. However, with laptops becoming more common and powerful they have omitted the need for such facilities in colleges which have gradually shifted towards using such spaces for 3D printing, sculpting needs. The importance of coding as an addition to most of the professional degrees has also shown its presence in the case of architecture. Architecture degree which already had a myriad of topics to choose from and fit in the five-year degree span has become more crowded due to the growing and changing needs of technology and the profession.

Earlier students were expected to struggle with the new user interface of the screen, keyboard, and mouse. The problem is attributed to differences in affordances and feedback system of the analog vs the digital interface. Coupled with that each digital software has a different interface and set of affordances that need to be learned and practised. So that the cognitive load required to operate the digital interface minimizes leading to the free capacity being dedicated to the design problem at hand. Also according to the theory of distributed cognition externalization tools should help in serving several functions (Zhang & Patel 2006). The most pertinent being provision of short-term or long-term memory aids and provision of knowledge and skills that are unavailable from internal representations (Zhang & Patel 2006). These functions can only be realized if students can develop a certain amount of intuition/automation concerning software use. Intuitive designs allow for each action to provide relevant feedback leading to quick learning (Norman 2013). Most of the old software CAD, ArchiCAD, Revit, etc. do not have an intuitive user interface. To elaborate, if there is a group of actions that lead to feedback rather than a single action, this makes the interface non-intuitive. This delayed lag leads to extra cognitive load as some steps need to be automated without specific feedback leading to the requirement of mental models. These mental models become automatic with practice but they increase the learning curve of the representative (digital software) tool. Moreover, many times wrong mental models are formed in the early stages, due to personal software exploration which leads to increased cognitive costs later when it has to be modified (). Many times some software does not provide clear feedback or provide feedback with too much information, which if left unprocessed creates further confusion and need for corrections.

In such a scenario it becomes imperative to understand if the millennial students getting fresh admission are somehow more advantageous over those students who had less exposure to computers or vice versa. Such a revelation would provide pedagogic answers such as; whether providing pedagogic support would benefit students with less computer exposure.

2. Impact of Sketching and Physical Modelling in Design Learning

Sketching and physical modelling has been ranked as one of the most important factors affecting creativity by 461 architecture graduate and post-graduate students (Daemei & Safari 2018). Additionally, in the case with drawing and sketching experience, it was seen that experts having developed skills were able to outperform their novices with less sketching experience (Kavakli et al. 2001). This has been attributed to the formation and exercise of mental imagery which helps in visual thinking, leading to better performance in ill-structured problems (Kavakli et al. 2001). There have also been reported cases of interactive mental imagery with experts who while solving a problem are continually shifting in between seeing, imaging, and drawing (Goldschmidt 1994). According to neuropsychology mental imagery has been linked to the generation, transformation, and inspection of images specifically related to spatial planning (Pearson et al. 2008; Kosslyn 2005). This provides mental imagery as a pertinent mental function for good design.

In design research, while using digital tools presence of mental imagery has not been reported so far. In a product design study, evaluative moves are said to increase while using digital tools, which indirectly point towards the presence of mental imagery (Lee et al. 2018). This paper, however, does not look for the presence of mental imagery directly rather it tries to evaluate the performance of students having previous computer learning to the ones with lesser learning. The finding can tentatively point towards the presence or absence of mental imagery connected to design.

3. Experiment Design

A. Sample

The experiment was carried out on first-year students belonging to the architecture department at the Indian Institute of Technology Kharagpur. They were a total of 38 students with 10 females and 28 male students. Out of these 38 students, 16 had ten or more than ten years of computer exposure. Twelve students had an experience of five to nine years with computer usage. While ten students had less than five years of computer exposure. Of these, the students having more than nine years of computer exposure were considered as experts in computer usage while five to nine years were considered intermediate level users, and the last group was considered as computer novices. The experiment had two sessions with one being analog utilizing sketching and physical modelling tools and other utilizing SketchUp.

Table 1: Classification of students according to years of computer exposure

Yrs. of comp. Expo.	No. of Students	Categorization
0-4 yrs.	10	Novice
5-9 yrs.	12	Intermediate
10 yrs. beyond	16	Expert

B. Question

The experiment question was a simple translation of a 2D graphic to its corresponding 3D options. The exercise was kept simple to ensure that the maximum cognitive load was generated due to the external representative tool. This would allow for easy identification of students who could produce several drawing transformations indicating that the cognitive load of the corresponding tool was less. The use of both analog and digital medium would also provide clarification over which tool should be preferred. Students having sufficient computer exposure were expected to outperform the ones with less experience. Three sets of these 2D drawings were created to ensure that students did not get influenced by each other while working and they had different questions during the two sessions. To ensure that the sets had the same problem difficulty the number of vertices and sides was kept similar.

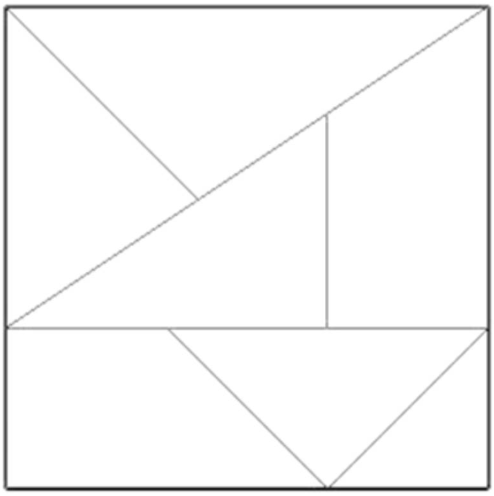


Fig.1: 2D figure question used in experiment Set A

Certain restrictions were imposed on the transformations to ensure that random generations and similar looking 3D geometry was avoided. The restrictions were as follows:

· Transformative moves were restricted to a cube whose size was governed by the side of the 2D rectangle.

· No new points were to be created on the lines apart from the vertices/intersections provided in the 2D drawing.

· New lines were to be created in the Z-axis perpendicular or angled to the XY plane.

· The height of the perpendicular lines in the Z-axis could be equal or half of the side of the square.

· Lines or planes angled to the XY plane were to be created by using the 3D perpendicular lines.

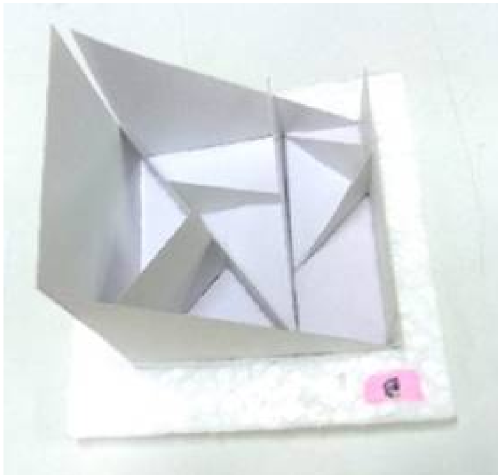


Fig. 2: 3D options generated from 2D figures using analog medium

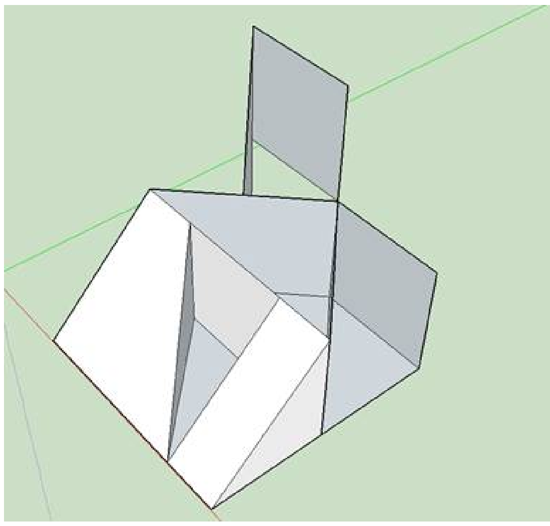


Fig. 2: 3D options generated from 2D figures using analog medium

· For a transition from one 3D geometry to another, a minimum of two transformative moves had to be made.

C. Tools

For analog, the students were provided with 2D drawings stuck on a thermocol base, and cardboards which could be easily inserted by making slits to create planes in the z-axis. While for digital tool Sketchup was used. The choice of software was based on its low learning curve, intuitive interface, and working similarity to analog tools. Students were provided with 2D drawing in Sketchup which was installed in separate computer systems of the CAD lab facility. Restrictions on the manipulation and creation of lines and points were provided to ensure that each 3D option created was significantly different from the other. A demonstration was provided to the students for analog tools, just before the onset of the exercise. In the case of Sketchup as most of the students were new to the software apart from two. A separate demonstration and doubt clarification session was held two weeks before the exercise. This time-lapse was to ensure that students had time to practice and get familiar with the Sketchup interface. A follow-up was also held to ensure that the students were practising in the interface with the necessary commands.

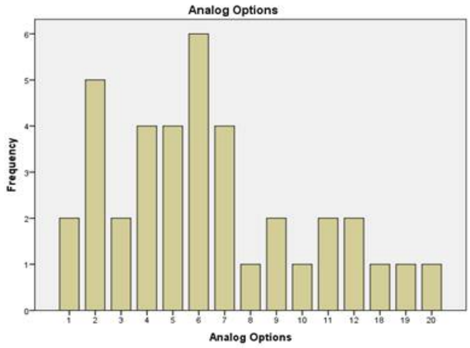
D. Duration and other Details

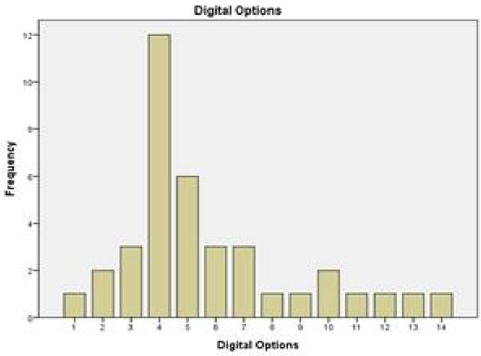
The exercise session was restricted to 30 mins each. This time duration was kept less to ensure that students were not getting fatigued especially while using the digital tool. To reduce the effect of the order of exercises (confounding variable). Students were divided into two batches A and B randomly so that when A was performing the analog exercise, B was in the CAD lab with Sketchup exercise. This order was reversed in the second session. In the end, questionnaire feedback forms were filled by the students regarding the experiment and externalization tools.

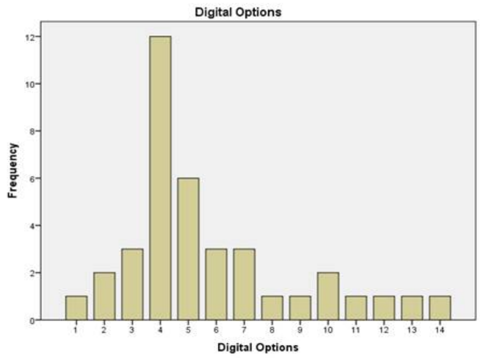
4. Results

A. Descriptive statistics

The data were analyzed in SPSS software. The mean of the total number of options generated for the sample population was 12.53. The standard deviation was 6.33. While the mean for total analog options generated was 6.76. The standard deviation was 4.7. The mean number of digital options generated was 5.74 with a standard deviation of 3.1. Clear normal distribution was not seen for the frequency distribution of analog, digital, or total options. This kept the data analysis open to the use of non-parametric analysis of dependencies.







Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation
Analog Options	38	1	20	6.76	4.704
Digital Options	38	1	14	5.74	3.108
Total Options	38	3	29	12.53	6.332
Prob. Difficulty	38	1	4	2.29	.835
Digital Difficulty	38	1	5	2.39	.946
Analog Difficulty	38	1	5	2.79	.963
Valid N (listwise)	38				

Fig. 4: Descriptive Statistics related to results. (a) Frequency distribution of analog options generated in the experiment. (b) Frequency distribution of digital options generated in the experiment. (c) Frequency distribution of total options generated in the experiment (d) Descriptive statistics of data from the

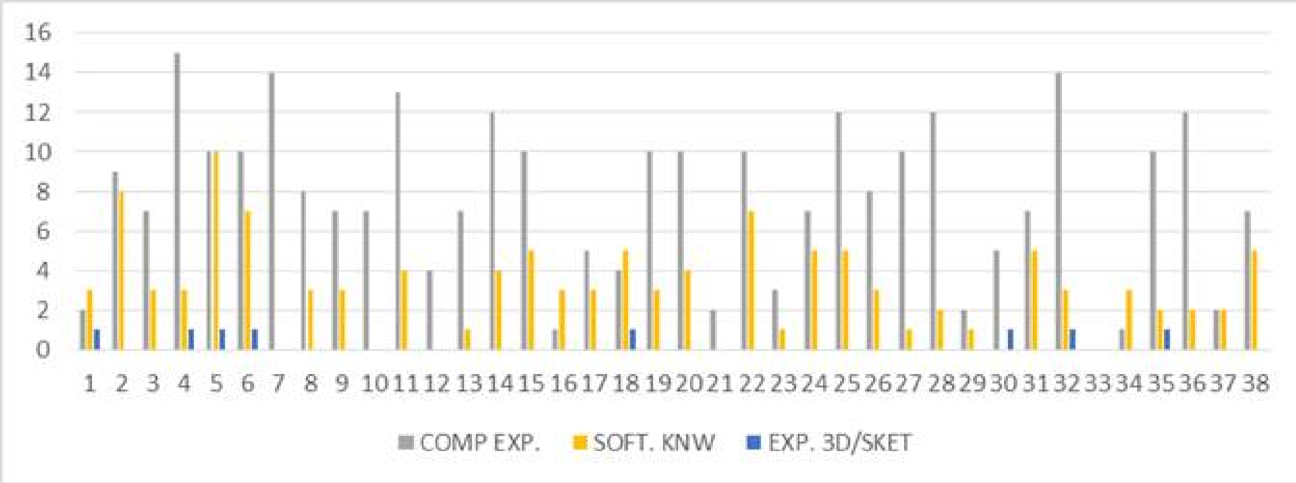


Fig. 5: Previous Computer learning sample-wise data. COMP EXP. - Computer Exposure (yrs), SOFT. KNW. - Number of software known, EXP. 3D/SKET - Experience in 3D software or SketchUp

B. Effect of previous computer learningFigure 5: Previous Computer learning sample-wise data. COMP EXP. - Computer Exposure (yrs), SOFT. KNW. - Number of software known, EXP. 3D/SKET - Experience in 3D software or SketchUp

The experiment was trying to find out the effect of previous computer learning on the digital performance of students. Pervious computer learning was measured by three independent variables; computer exposure (years), number of software known; 3D/Sketchup experience. Exposure of 3D drafting and modelling was negligible in the sample population with eight having basic exposure to such software. Also, the experiment could have measured the effect of exposure to physical modelling and sketching experience. However, it was seen that the group was not well distributed with most of the students having some experience apart from four students. This prompted us to consider only number of years of computer exposure as one of the independent variables influencing the study. As discussed before more exposure would lead to intuitive behaviour towards the computer interface leading to better performance.
Kruskal Wallis test was used to analyze the variances between groups due to more than two groups present in most of the independent variables and their unequal sizes. Also the dependent variable data under analysis were not normally distributed with outliers which could not have been omitted. The results of Kruskal Wallis test revealed no statistically significant effect of computer exposure on digital performance of the students (Table 2). It should be noted that the students were divided into three groups; expert, intermediate, novice. Also the number of software known by the students had no effect on their digital performance (Table 3). Further, the knowledge and experience of 3D software or Sketchup (used in the study) was also found to be statistically insignificant on the digital performance of students (Table 4). This tentatively points towards the absence or weak mental imagery formation while using digital 3D tools.

Ranks

	Computer Exp.	N	Mean Rank
Digital Options	0-4 years exp	10	22.50
	5-9 years exp	12	19.42
	10-15 years exp	16	17.69
	Total	38	
Analog Options	0-4 years exp	10	24.40
	5-9 years exp	12	16.83
	10-15 years exp	16	18.44
	Total	38	

Test Statistics[a,b]

	Digital Options	Analog Options
Chi-Square	1.199	2.809
df	2	2
Asymp. Sig.	.549	.245

a. Kruskal Wallis Test

b. Grouping Variable: Computer Exp.

Fig. 6: SPSS table using Kruskal-Wallis test for effect of computer exposure (a) Ranks of Kruskal Wallis test (b) Test Statistics.

Ranks

	Software Known	N	Mean Rank
Digital Options	0	6	18.25
	1	4	26.88
	2	4	14.63
	3	11	21.36
	4	3	21.00
	5	6	11.92
	7	2	23.75
	8	1	36.00
	10	1	12.50
	Total	38	

Test Statistics[a,b]

	Digital Options
Chi-Square	8.988
df	8
Asymp. Sig.	.343

a. Kruskal Wallis Test

b. Grouping Variable: Software Known

Fig. 7: SPSS table using Kruskal-Wallis test for effect number of software known (a) Ranks of Kruskal Wallis test (b) Test Statistics.

Ranks

	3D/Sketchup Exp.	N	Mean Rank
Digital Options	No experience	30	20.68
	Experienced	8	15.06
	Total	38	

Test Statistics[a,b]

	Digital Options
Chi-Square	1.677
df	1
Asymp. Sig.	.195

a. Kruskal Wallis Test

b. Grouping Variable: 3D/Sketchup Exp.

Fig. 8: SPSS table using Kruskal-Wallis test for effect of 3D/Sketchup software known (a) Ranks of Kruskal Wallis test (b) Test Statistics.

C. Other Results

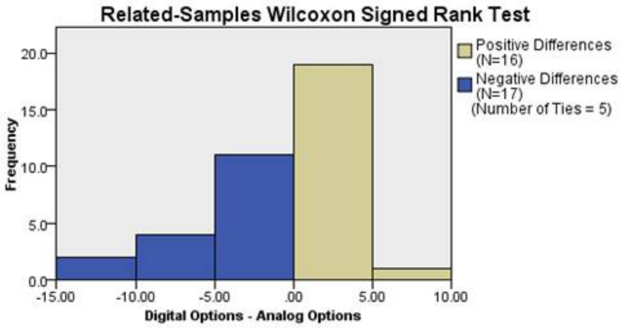
The study also tried to see if there was a medium that produced better results for 2D to 3D translation. To analyze this first a paired sample t-test was used. The analog and digital option variables, in this case, were considered as paired data since the questions for 2D to 3D translation were the same. Additionally, each student had done both the exercises in different sessions. However, since the variable data was not normally distributed and had outliers, a non-parametric test Wilcoxon Signed Rank test (WSRT) was also used. Results from both the tests pointed towards a statistically nonsignificant difference between using analog or digital medium for 2D to 3D translation. T-test had a significance level of 0.199 while WSRT has a significance of 0.337.

Hypothesis Test Summary

	Null Hypothesis	Test	Sig.	Decision
1	The median of differences between Analog Options and Digital Options equals 0.	Related-Samples Wilcoxon Signed Rank Test	.337	Retain the null hypothesis.

Asymptotic significances are displayed. The significance level is .05.

(a)



(b)

Fig. 9: Wilcoxon Signed rank test (Related-samples) for medium preference.(a) & (b) A Mann-Whitney test was also carried out to analyze the differences in performance between male and female sample population. The difference between their populations was statistically not significant. However, there was a big gap between the sample groups with 10 female students in a total of 38.

Test Statistics[a]

	Total Options
Mann-Whitney U	90.000
Wilcoxon W	145.000
Z	-1.662
Asymp. Sig. (2-tailed)	.097
Exact Sig. [2*(1-tailed Sig.)]	.101[b]

a. Grouping Variable: Gender

b. Not corrected for ties.

(a)

Ranks

	Gender	N	Mean Rank	Sum of Ranks
Total Options	Male	28	21.29	596.00
	Female	10	14.50	145.00
	Total	38		

(b)

Fig.10: Mann-Whitney test for effect of gender on performance. (a) Test Statistics (b) Mann-Whitney test Ranks

Similarly, the correlation between analog options and digital options produced by students was analyzed. Here again, a parametric and non-parametric test was used. For the parametric test, Pearson's coefficient was used. The test revealed a weak correlation (0.309) between analog and digital options generation with a statistical significance of 0.03. In the case of non-parametric test Spearman's rho was used which revealed a weaker correlation (0.288) with a higher significance of 0.04. The results indicate that the student's performance was in some way linked across the two medium options. In other words, the students who performed well in one medium did not perform poorly in the other medium. Here the effect of individual effort probably can explain a correlation between the two.

Correlations

			Analog Options	Digital Options
Spearman's rho	Analog Options	Correlation Coefficient	1.000	.309*
		Sig. (1-tailed)	.	.030
		N	38	38
	Digital Options	Correlation Coefficient	.309*	1.000
		Sig. (1-tailed)	.030	.
		N	38	38

*. Correlation is significant at the 0.05 level (1-tailed).

Fig. 11: Spearman's rho correlation between assessed problem difficulty and options (total/analog/digital) generated

Correlations

			Analog Options	Digital Options	Total Options	Prob. Difficulty
Spearman's rho	Analog Options	Correlation Coefficient	1.000	.309	.843**	-.349*
		Sig. (2-tailed)	.	.059	.000	.032
		N	38	38	38	38
	Digital Options	Correlation Coefficient	.309	1.000	.725**	-.314
		Sig. (2-tailed)	.059	.	.000	.055
		N	38	38	38	38
	Total Options	Correlation Coefficient	.843**	.725**	1.000	-.396*
		Sig. (2-tailed)	.000	.000	.	.014
		N	38	38	38	38
	Prob. Difficulty	Correlation Coefficient	-.349*	-.314	-.396*	1.000
		Sig. (2-tailed)	.032	.055	.014	.
		N	38	38	38	38

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

Fig. 12: Spearman's rho (non-parametric) correlation test for relation between analog and digital options generated.

Another finding was related to the assessed problem difficulty of 2D to 3D translation and total options generated by the students. A Spearman's Rho test for correlation revealed a negative co-relation of 0.396 with a significance of 0.014. This points out that students who assessed the experiment problem to be difficult produced more number of 3D options. This is counter-intuitive and could be explained based on the behavioural psychology of the students. They exerted more effort when they found that the problem was difficult. Individually analog options correlation stood at -0.349 with a significance of 0.032 while for digital options the correlation was -0.314 with a significance of 0.055.

5. Discussion & Conclusion

The experiment was carried out to study the effect of previous computer learning on early architecture education. A designed experiment that required students to translate 2D to possible 3D options using both analog and digital mediums was used. The study was carried out on a sample size of 38. Previous computer learning data was collected in terms of exposure to the computer (years), software known, and exposure to 3D/Sketchup software. All these variables were found to be statistically insignificant on the digital and overall performance of the students in the experiment. This somehow indicated that there was no additional need for colleges to invest time and resources into training and preparing students with no previous computer learning.

Apart from these main findings, some other effects were also studied

- The first one being the performance effect of the medium (analog or digital). No statistically significant difference was found between the two mediums used by students for 2D to 3D translation.

- The effect of gender was also insignificant to the total option generated by each sample.

- It was found that the students' performance did not drastically change while switching in between mediums.

- The students' performance and their rating of problem difficulty were negatively related, with anticipation of the difficult problem leading to better performance.

The results of the effect of knowledge of a 3D digital tool also were insignificant, tentatively pointing towards the absence or weak mental imagery formation while using digital 3D tools. However, the results of this study were limited to an institution with small sample size, replication of results would lead to external validation of conclusions on a larger population. The method adopted in the study was experimental and tried to reduce the effect of other influencing variables by making the exercise different from real-studio setting. This could also affect the ecological validity of the findings.

The learning and practice of computers did not impact the performance of student's unlike the case of sketching and physical modelling in design education. There have been various studies pointing towards the benefit of sketching and physical modelling in developing mental imagery. However, so far no study had looked into the effect of computer learning and software knowledge on the internal representation of designers. The paper addressed the gap in research and pointed towards a possibility where mental imagery could be weak while using 3D digital tools. Design learning as taught in the architecture studio aims to develop mental imagery and related design knowledge (Eastman 2001). Conceptual phase of design which is directed by manual sketching leads to the deployment of mental imagery, resulting in enhanced visual perception and reflective conversations (Goldschmidt 1994; Goldschmidt 1995; Schon and Wiggins 1992). According to the findings, the use of computer for design learning and conceptual design could be restrictive. More study needs to be done in this direction to ascertain or clarify the findings.

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