APPRASIAL OF DESIGN STUDIO METHODOLOGIES

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Abstract. This paper investigates the relationship between different design approaches and their effectiveness in the formulation of design concepts. This inquiry will focus on the computer as the sole design and developmental tool.

The research employs a short design programme, a small building with a given urban site, as its investigative vehicle. Nineteen second year students of the Mackintosh School of Architecture were monitored and their design progress evaluated. They were split into two groups: one used CAD and AEC as the only drawing and modelling tool, tutorial and review, and another used conventional tools of drawing and model making (mixed media). Structured interviews and personal observations were used as a means for data collection. Questionnaires were administered to students and their response was analysed using the statistical programme SPSS (Statistical Package for the Social Sciences). The Mann-Whitney test was used to test the Null Hypothesis that different design approaches will not produce different design outcomes. Correlation, Regression and the $X^2$ test of independence were also employed to screen data and identify patterns of relationships.

1. Introduction

The intention of both authors was to investigate the effectiveness of the computer as the sole design and developmental tool. This research has set up, monitored and analysed a short design programme for 19 second year students at the beginning of their academic year.

It was considered that at this stage in their careers the students would only have had a relatively small exposure to the design process and consequently not had time to establish and fix patterns of designing. So they are usually still very open to a variety of opportunities.

They were split into two groups. One group used 2D and 3D AutoCAD AEC as the only drawing and modelling tools. Another, the mixed media group, used conventional tools for drawing and model making and were free to use a combination of conventional and computing tools. However, for sampling reasons the latter two groups were combined in one group called the ‘mixed media’ group. Attitudes towards CAD were measured at two points in time, before and after using CAD to solve the design problem. The after experiment included only the CAD group. Students’ progress was monitored and a comparative appraisal of their experience was made. The experiment was treated as open-ended research and we had no perceived expectation of the outcome.
2. Design Brief

Students were asked to design and locate a small pavilion within an urban landscape. They had previously mapped and analysed an area of neglected wasteland and made proposals for the design of the urban park. This became their terms of reference within which they were to site the building. The intention was to generate a greater connection and interaction between building and landscape resulting in a more integrated architectural statement.

A cafe bar and sculpture gallery were the two options chosen for the pavilion. They were given an internal floor area of 150 square metres with connected external space for either seating or display of sculpture as appropriate. Both were to have service areas for food preparation, storage, refuse, servery, and toilets. The students were asked to design a building that would satisfy the every day functional requirements, meet the needs of an event or party for 40 people, and respond to both twenty four hour use and seasonal change.

Consideration was to be given to its total aesthetic presence as it was visible from all around and even from above. Materiality and colour were to be examined in terms of structure, construction and experience. The whole programme from initiation to review lasted five weeks.

3. Analysis of student response: Assessment of outcome using SPSS-PC

SPSS-PC was used to analyse questionnaire returns. Several statistical tests were chosen and carried out to screen and analyse the data. The criteria for choosing a test depended upon three considerations (Kinneir and Gray, 1986): the research question, i.e. the hypothesis; the nature of data and its scale of measurement (nominal (i.e. male, female), ordinal (i.e. very satisfied, satisfied, unsatisfied), interval (i.e. height, examination score)); the research design (related/unrelated samples, one, two, k samples.

This bar chart is a descriptive statistic for the extent of students' past familiarity with Computing in general.

![Graph showing gender differences in past Computing experience](image)

*Figure 1. Gender differences on past Computing experience.*
Q: Describe your overall feeling about using CAD tools and / or conventional tools (paper and pencil) for design development?

We can see from the Kendall's non-parametric test that the correlation coefficient of 0.598 is significant. It indicates a positive attitude to both

<table>
<thead>
<tr>
<th>TABLE 1. The strength of the relationship between the two variables</th>
</tr>
</thead>
<tbody>
<tr>
<td>Correlation Coefficient</td>
</tr>
<tr>
<td>--------------------------</td>
</tr>
<tr>
<td>overall feeling about conventional tools</td>
</tr>
<tr>
<td>overall feeling about CAD tools</td>
</tr>
<tr>
<td>overall feeling about CAD tools</td>
</tr>
<tr>
<td>overall feeling about conventional tools</td>
</tr>
<tr>
<td>overall feeling about CAD tools</td>
</tr>
<tr>
<td>overall feeling about conventional tools</td>
</tr>
</tbody>
</table>

Correlation is significant at the .01 level (1-tailed).

Both conventional and CAD are seen as beneficial tools contributing to the design process. This implies that the subjective dimensions of these two variables overlap in student minds.

To explore the above relationship further, SPSS was used to perform the Median assessment which also shows that the feeling about the future use for computers is positive but that it has a broader banding between 3 to 5. While it is evident that the value given to conventional tools (particularly sketching) is more consistent with a high median of 5. Although the overall feeling about both mediums is positive it is worth noting that the female response to both CAD tools and conventional tools is even more positive and in the case of CAD significantly more positive (Figure 3). Why the difference? This might be because our female participants are more openly positive about their education and the potential opportunities it can offer and as a consequence see the all-round benefits of CAD tools more clearly.

The analysis also shows that there is a direct relationship between the attitude to the two different mediums (Figure 4). It highlights an increasing negative relationship between “attitude toward using CAD instead of conventional tools
(DV- dependent variable)”, and the “extent to which conventional sketching was used in this design exercise” (IV- independent variable). The R-squared on the right of the Regression line shows a variance of 32%, a change in IV causes a 32% change in the DV. This reinforces our understanding that the more one medium is used (e.g. conventional) the less we will be positive about the other (e.g. CAD) and vice versa.

![Figure 3. Male/Female attitudes towards different design media](image1)

**Figure 3.** Male/Female attitudes towards different design media

![Figure 4. The Regression line relating the two variables](image2)

**Figure 4.** The Regression line relating the two variables

The regression equation, obtained from SPSS, can be written as:

\[
\text{attitude toward using CAD instead of conventional tools (DV)} = 4.668 - 0.646x
\]

(\text{extent to which conventional sketching was used in this design exercise-IV}). So if a student scored 3 on IV which means he used conventional sketching occasionally, his attitude toward the DV will be \(4.668 - 0.646 \times 3 = 2.73\), [which means an attitude between “negative” (2) and “neutral” (3)].

![Figure 5. Students' perception of CAD](image3)

**Figure 5.** Students' perception of CAD

Q: What do you think this programme of using 2D and 3D Auto CAD, AEC and Accurender 2.0 will offer you?

It was apparent (Fig. 5) that the perception of CAD was that it would be beneficial in helping creative opportunities, in improving communication skills and improving productivity as the mean was always above neutral (3). However it is very evident that our participants perceived that CAD's greatest contribution would be in terms of improving productivity.
APPRAISAL OF DESIGN STUDIO METHODOLOGIES

To test the null hypothesis, it is important to see whether the two groups, CAD and mixed media, differ in their attitudes towards the benefits of CAD. It is for this reason that the Mann-Whitney test (TABLE 2.) for two independent groups was used.

**TABLE 2.** The Mann-Whitney test with Significance values.

<table>
<thead>
<tr>
<th>Test Statistic</th>
<th>Using CAD helping creative opportunity</th>
<th>Using CAD improves communication</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mann-Whitney U</td>
<td>18.500</td>
<td>17.500</td>
</tr>
<tr>
<td>Wilcoxon W</td>
<td>71.000</td>
<td>53.500</td>
</tr>
<tr>
<td>Z</td>
<td>-1.774</td>
<td>-2.276</td>
</tr>
<tr>
<td>Asmp. Sig. b</td>
<td>.044</td>
<td>.023</td>
</tr>
<tr>
<td>Exact Sig.</td>
<td>.048*</td>
<td>.026*</td>
</tr>
</tbody>
</table>

a. Not corrected for ties.  
b. Grouping Variable: student category

This table shows that the Mann-Whitney value on “using CAD helps creative opportunity” is 18.0 and on “using CAD improves communication” is 17.5. Both figures are below the value of 19 (Clegg, 1995, p.166) which must not be exceeded to reject the null hypothesis, the hypothesis of no difference in attitude between the two groups.

As a linear design tool AEC is excellent. It demands that the designer make decisions to make the next drawn move. Without a decision there is no progress. Once a proposal or modification is made it can be recorded and viewed in different ways and drawing systems simultaneously on the screen which allows a greater understanding of the design implications. These can then be appraised and the next move considered and made. The process forces the pace of decision making achieving greater productivity and is ideal in a linear design development situation.

**Q: How do you see the future use of computers both in architectural education and in architectural practice?**

Analysis of student response showed that all participants considered that the computers contribution to both education and practice will increase significantly in the future. This was thought to be more so in practice than education. Using the Wilcoxon signed ranks test it was clear that there was no significance in the difference in attitude towards these two variables and that the reasons for variance could coexist without conflict. This is evident from the value of significance (0.271) obtained which is well above the recommendation that the level of significance should be equal to or less than 0.05 to reject the no “difference” assumption. Presumably it was considered by the participants that the perceived value of the computer in both production drawing and in terms of productivity might be slightly more valued in practice than in education. It
may be reasoned that the computer's use could increase more in practice than in education where the emphasis is more concentrated on the students intellectual development and design thinking. It might also be related to educational institutions perceived lack of funding to implement the most up to date technology.

![Graph showing time spent on aspects of design](image)

**Figure 6.** Time spent on aspects of the design.

Q: What % of time was given to learning the AEC and Accurender programme compared to designing?

The graph shows that a large part of the project time was given to learning the AEC and Accurender and it was greater than the amount of time spent on designing (by 12%). This reduced the amount of time available to design and affected the level to which the students using AEC were able to develop their ideas. Consequently most of the group didn’t examine the structural and construction aspects as much as the two groups who were working more conventionally. This made it an imbalanced comparison with those who were using only conventional tools as they were able to dedicate all their time to designing. We did know this in principle before we started but not to what extent it would impact on the research. We none the less felt the experiment would be a worthwhile.

Q: How do you feel about having your design crits on the computer?

The results that technical problems impinged on the perceived value of the Computer Crit. It is still evident from the responses to our open ended question related to the above question that the students recognised key areas of advantage over the conventional review situation. Reviews using a portable hooked up to a video projector allow images to be projected much larger. It had the advantage over a conventional review, of offering easier viewing of images by all and a clear sense of a focused discussion around images or details selected and zoomed onto the screen. This in itself helps concentration. The review has the potential to be far more interactive as information can be recalled in response to queries. It was also acknowledged that with AEC it is possible to achieve a greater awareness of the spatial and formal qualities of a design and particularly with 3D animated walk throughs be able to equate the design proposals to the real situation of walking through the building.

Q: In the process of searching for your design concept have you used conventional sketching?

It was found that the majority used conventional sketching in the process however it was a minority who used it frequently. An obvious reason for some
of this use of sketching was that at the start of the programme the students initial exploration of ideas was hampered by their lack of proficiency with the computer. At this stage in the process it is necessary to be able to make marks that can flow unhampered by overt conscious decision making. Designers need to think freely through drawing. Another reason is that the AEC sketch option has limitations as a means of drawing. The use of the mouse to draw free hand takes more time and demands far more control than pencil and paper. It does not have the range of thickness and intensity and it therefore cannot express the weight and emphasis intended in aspects of a drawn idea. The lack of fluidity hinders the range, speed and flow of drawing as a design tool in the initial stages when designers need freedom to explore ideas through drawing.

TABLE 3. The Chi-Square Test of independence between two variables.

<table>
<thead>
<tr>
<th></th>
<th>Value</th>
<th>df</th>
<th>Asymp. Sig (2-sided)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reaction</td>
<td>17.333</td>
<td>9</td>
<td>.044</td>
</tr>
<tr>
<td>Likelihood Ratio</td>
<td>15.585</td>
<td>9</td>
<td>.076</td>
</tr>
<tr>
<td>Linear-by-Linear Association</td>
<td>2.350</td>
<td>1</td>
<td>.136</td>
</tr>
</tbody>
</table>

* 16 cells (100.0%) have expected count less than 5. The minimum expected count is 13.

It was apparent from the Crosstabulation analysis and the Chi-Square test that the students who rarely use conventional sketching were also those who responded positively or very positively to CAD. The obtained Chi-Square figure of 17.33 at df=9 is above the critical value of 16.92 (Clegg, 1995, p. 175). Thus the hypothesis of no relationship between "overall attitude toward using CAD instead of conventional tools" and the "extent of sketching use when searching for a design concept" should be rejected. It is obvious as those individuals who are competent with CAD are able to achieve without resorting to other means.

Q: Do you feel using CAD has improved your design skills and attitude?
It was found that student response was very positive. Students' comments indicated that they tended to think more holistically. AEC allows the student to see his or her proposal in multiple views at the same time on the screen. This can quite easily include plan, section, elevation, axonometric and perspective side by side. It allows the designer to see the implications and potential of any design move more fully and in so doing open up options which might otherwise not have been so evident. The perceived sequence of working from plan then section then three dimensionally was broken and a 3D exploration occurred simultaneously with the planning and sectional organisation.

Q: How has CAD affected your decision making compared with the conventional process?
Various bar charts show that on balance the participants felt that the use of CAD was beneficial. The majority felt that it had improved design skills and attitude and made a positive contribution to their thinking process despite 3 participants view that it had made their progress slower.
Q: Thought management and structure: do you feel that using CAD has made you spend more time thinking about rather than sketching the design concept?

The Pearson Chi-square ($X^2$), TABLE 4, is 4.44 at df=1. From statistical tables (Clegg, 1995, p. 175), the critical value of $X^2$ is 3.841 which is below our obtained value. This indicates a significant relationship between the perceived improvement of design skill in terms of thought process and time management, and the use of CAD. Both time management and the integration of programmes like Deflect seem crucial in the response to this question. The ability to simplify and reduce repetitive drawing tasks as well as layer information liberates time which can be used to think, refine and develop a design.

TABLE 4. The Chi-Square Test of independence between two variables.

<table>
<thead>
<tr>
<th>Chi-Square Tests</th>
<th>Value</th>
<th>df</th>
<th>Asymp. Sig. (2-sided)</th>
<th>Exact Sig. (2-sided)</th>
<th>Exact Sig. (1-sided)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pearson Chi-Square</td>
<td>4.444</td>
<td>1</td>
<td>.035</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Continuity</td>
<td>1.000</td>
<td>1</td>
<td>.316</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Likelihood Ratio</td>
<td>5.178</td>
<td>1</td>
<td>.023</td>
<td>.107</td>
<td>.107</td>
</tr>
<tr>
<td>Fisher's Exact</td>
<td></td>
<td></td>
<td></td>
<td>.549</td>
<td></td>
</tr>
<tr>
<td>Test</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Linear-by-Linear</td>
<td>3.868</td>
<td>1</td>
<td>.050</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Association</td>
<td>N of Valid Cases</td>
<td>8</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- a. Computed only for a 2x2 table
- b. 4 cells (50.0%) have expected count less than 5. The minimum expected count is 7.5.

For example if a change or modification to a drawing is made it is made to all the relevant drawings simultaneously so saving time adjusting each drawing separately. Also the option to create layers gives the designer the opportunity to produce additional degrees and types of information and detail. This in turn allows the designer to convey an idea fully or abstract certain information for further examination and development. It also reduces the need to duplicate drawings. This means that less time is being spent on the activity of drawing and repetitive drawing and more time can be given to thinking and development. The designer is also able to use the same base drawings to think about and develop different aspects of the design.

Q: In which of the following areas do you feel that AEC and Accurender have helped you most during the design process?

The t-test was used to identify CAD areas that helped most during the design process. It was found that there were four areas that had a significance of less than 0.05. The areas that were considered to have helped most during the design process were: 3D design and perspective ($t=7.0$), Trees and landscape ($t=3.87$), compositional design and solid modelling ($t=8.0$) and sunlight and shadow maps ($t=2.37$)
4. Project Descriptions : Selected Samples

*Figure 7.* Eleanor Baxter's idea for a Café in Kelvinbridge Park.

The concept developed from her exploration of tectonics. The site was cleared. Part of the land was tilted upward along the line of a fault and an inclined cuboid was pushed out from below the ground displacing some of the rock. The cuboid was subsequently occupied as a Café. The image shows both 2D and 3D drawings in four viewports. It illustrates the way multi view imaging helped her develop the three dimensional quality of her proposal far more than she had in previous projects.

*Figure 8.* shows Glen Massey's Café proposal for Kelvinbridge Park. Glen was using Accurender to appreciate the qualities of daylight in relation to his proposal. Although it shows the main space with the roof removed, (it is one of a sequence), it still begins to reveal the changing nature of the space in sunlight.
5. Conclusion

5.1 Testing the null hypothesis via statistical analysis of attitudes: The Mann-Whitney test (TABLE 2) confirms a difference in attitudes between the CAD group and the mixed media group toward “using CAD helps creative opportunity” and “using CAD improves communication”. This difference must have been the result of exposure to different design approaches. The Chi-square test (TABLE 3) shows that the extent to which students used conventional sketching when searching for a design solution related to their overall attitude toward CAD use. Fig. 4 depicts a negative relationship between the two concepts, i.e. an increase in one will cause a decrease in another. This suggests that the mixed media group who spent more time on conventional sketching than the other group would have responded negatively toward using CAD. Again this emphasises a difference in attitude between the two groups. TABLE 4 reveals a significant relationship between the perceived improvement of design skill in terms of thought process and time management, and the use of CAD. The t-test identifies four areas in CAD that helped most during the design process. By implication the CAD group will produce designs that are different from the mixed media group. In conclusion the null hypothesis should be rejected in favour of an alternative hypothesis, that different design approaches will produce different design outcomes.

5.2 Testing the null hypothesis via observation of outcome: 3D and animated walk-throughs were perceived as significant beneficial changes to the design process and stimulated far more three dimensionally thinking. It was acknowledged that with AEC it is possible to achieve a greater awareness of the spatial and formal qualities of a proposal. With 3D animated walk throughs we are able to equate the design proposals to the real situation of walking through the building. The link with Accurender also represents a change in structure and provided the opportunity to examine spatial and formal arrangements in real daylight conditions. The students tended to think more holistically as AEC allowed them to see their proposal in multiple views simultaneously on the screen. This provided the opportunity to see the implications and potential of any design move more fully and opened up new possibilities. These beneficial contributions to the design process were evident in the student design outcomes. Far more three dimensional images were produced by the AEC group. The park context and landscaping were described more thoroughly in 3D than by the other group. The Accurender programme was used to produce the only inhabited perspectives with natural light rendering.

References