Physical or Digital: Alternative Approaches to Modelling for a Participatory Design Environment

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Many of those who are advocating the use of computers in planning and design are promoting the internet as a way of involving non-experts. Although there is a great deal to be said for such an approach, the role of direct face-to-face communications remains important and yet relatively little has been done to investigate how computers can be of assistance in such a setting. This paper will present the results of an experiment in which a commercially available, but relatively inexpensive, computer-aided architectural design (CAAD) package has been used to facilitate participatory design. The results indicate that such an approach can significantly improve the quality of design and also enhance the experience of those who have participated in the design process.

1. INTRODUCTION

The idea that the public should have some involvement in the design of the buildings they occupy is not new, with such modern movement figures as Walter Gropius advocating public participation in architecture in the 1940s [1, 2]. However, the major thrust towards participatory design emerged in the 1960s as one manifestation of the radicalism of the period [3]. Arnstein developed her 'ladder' of participation in 1969 [4] and through the 1970s there were a growing number of projects, mainly housing developments, in which residents and local people were involved in both design and management. More recently, there has been renewed interest in community participation, promoted in the UK by the government as part of its policy of social inclusion [5]; in the US by the Civic Practices Network, and internationally by IAP2, the International Association for Public Participation [6].

Over the years a number of methods have been developed to facilitate the participatory design process. Wates provides a comprehensive summary of these, ranging from Action Planning Events to a Video Soapbox [7]. All are designed to engage the local community and most use relatively simple technology. For example, the Interactive Display is a display board which contains text, maps, photographs and post-it notes to which participants can add their own comments in order to further the debate. When it comes to involving non-experts in design, Wates identifies three ways of doing this, ranging from a Design Game, where participants move predetermined elements around on a plan, through a Design Workshop, where a small group of professionals and lay people work together on a design issue, to a Design Fest or Charrette. This is a major event where multidisciplinary teams work together over a period of a few days in order to produce creative solutions to a major design problem. The event is held in public and ends with an exhibition and symposium where everyone is encouraged to respond to the ideas that have been generated. One of the most successful approaches to participatory design in the UK is *Planning for Real*, a form of Design Workshop developed by the Neighbourhood Initiatives Foundation which, "uses 3D models of a local area on which people can make suggestions for change" [8].

During participatory events a wide range of tools are employed in order to represent design ideas. Conventional architectural drawings are in evidence although, because ideas are evolving rapidly, there is a premium on quick methods of representation. Freehand sketches and rough models tend to be very popular as they are fast to produce and their three-dimensional nature makes them easy to understand. In *Planning for Real* events the 3D models tend to be very simple and fashioned from ordinary sheets of paper using scissors and tape. Although these can look crude, they can be produced quickly and there are few inhibitions about altering them or even throwing them away and starting again.

As computer technology has permeated the design office it has found its way into participatory design events. In design charrettes, where groups of professionals are working in teams, computers are much in evidence, although the technology tends to be used for presentation rather than design. Outside the arena of architectural design there are examples of computer-based environments which have been created specifically for design exploration. The *Envisionment and Discovery Collaboratory*, or EDC [9], comprises a horizontal electronic whiteboard where participants interact with a computer simulation by manipulating physical objects which represent the design elements. The table is known as the *action space* and there is also a second vertical electronic whiteboard which is used to present information about the problem in hand. The most mature prototype that has been developed so far is to support citizens in the design of a transportation system for their neighbourhood.

One area where much more use has been made of information and communications technology is in the development of web-based applications to support participatory design [10]. Given the power of the internet to provide access to information and to facilitate two way communications, it is hardly surprising that it has been employed to engage people in the planning process. At the simplest level the internet is used to communicate information about applications that have been received for development. For example, the London Borough of Wandsworth has a site [11] where details of all current planning applications can be viewed and comments emailed to the relevant planning officer. This kind of service is becoming fairly widespread in the UK, although it offers no more than can be gained from a visit to the local planning office. A more ambitious project is described by Hudson-Smith et al. [12] who created a web site to facilitate what they describe as 'net participation' for a deprived housing estate in London. The project aimed to provide a service to some 6,000 residents of the Woodberry Down regeneration area. The web site comprised four main elements: text-based information, maps and panoramas of the existing site, a discussion forum, and various options for the future shown as three-dimensional computer models. However, there are significant technical difficulties in delivering such a rich mix of information types across the internet, particularly where the target population is deprived and unlikely to have access to the necessary equipment.

Although there is clearly great potential in the internet as a way of involving non-experts in planning and design, there are also ways in which new technology can help with face-to-face communications, of the kind that is evident in design charrettes and *Planning for Real events*. Over the past twenty years computer-based tools have developed to the point where they can produce sophisticated three-dimensional models of buildings, from which high quality images and animations can be generated. The outputs from this kind of software are not abstract, like conventional architectural drawings, and are therefore very accessible to non-experts. When it first became available, 3D modelling software was both expensive and difficult to use and was normally only found within design practices, although there are examples where it has been used to help with the process of design negotiation between individual applicants and planning officers [13, 14]. However, in recent years new CAAD products have appeared which are both easier to use and relatively inexpensive. One of these, SketchUp, is so user-friendly that it has been used by school children to help them understand the design process by using it themselves [15].

Software such as this would seem to have the potential to aid participatory design, not by replacing physical models and drawings, but by supplementing them and providing a way of developing and visualising design ideas quickly and easily. The way that SketchUp works is to present the user with a three-dimensional workspace in which fully rendered objects are created and manipulated in real-time using a method that is analogous to physical modelling. Traditional CAAD packages tend to be fairly abstract in the way that they operate, whereas SketchUp behaves in the way that a naive user would expect design software to behave. This means that many of the benefits that design practices currently gain from using CAAD can be made available to non-experts. These include quicker and more accurate model-building, the reuse of components though copying and pasting, and the use of existing urban models to provide the context for a new development. The results that can be produced by using these tools are much more convincing and professional than the simple paper and post-it note models that are traditional in participatory design settings.

2. THE EXPERIMENT

In order to test whether the use of the kind of CAAD system that has been described would really be of benefit to non-experts, an experiment was carried out comparing the use of SketchUp with the use of physical models. An initial study was carried out to evaluate available CAAD packages and SketchUp was chosen because of its ease of use for 3D modelling, its general availability, and its low cost. This is an important issue, given that participatory design is often carried out on a restricted budget. It was also felt to be important to use a program that was robust and fully documented, which ruled-out experimental software such as Moderato [16] or the Electronic Cocktail Napkin [17].

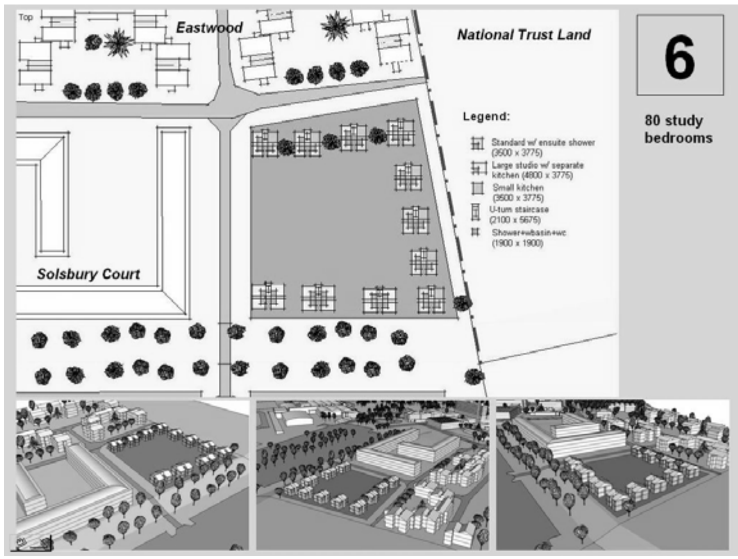
The subjects of the experiment were students at the University of Bath with no previous experience of architectural design. Both undergraduate and postgraduate students were involved and were divided into two similar groups, each with 40 members. The task involved the design of new student residences on a site adjacent to existing residences on the university campus. Each participant worked on the problem for about an hour with a trained architect acting as a facilitator.

Each experimental session followed a standard format. The participants were introduced to the various issues that should be considered when designing student residences. They were told that cost was an important issue and that the capital cost of the building was a critical factor in calculating the rental cost of each study bedroom. They were shown some standard ways of designing the individual rooms and the options for including additional facilities, such as en suite bathrooms or communal lounges. They were also shown how individual rooms could be grouped around shared kitchens and linked by horizontal and vertical circulation. This provided them with a range of building blocks that they could begin to use for design. The software environment was therefore not just the CAAD package, but also included the pre-built elements of rooms and groups of rooms that could be used to create a building. Although participants were not limited to only using these building blocks, they did provide a starting point which allowed a design to develop fairly swiftly.

The site, which was adjacent to existing student housing, was also introduced and the various constraints that impinged on it were described. These included planning constraints imposed by the local authority which limited the visual impact of any new development and this, in turn, had implications for any proposed building's height. As the university had already commissioned architects to design student housing for the site this was a 'real' project, which engendered a sense of engagement within the participants. They were asked to provide what they felt was the most appropriate mix of room types and told that costs could be reduced by maximising the density of the development and reducing excess circulation. However, this had to be done in such a way that the building still complied with the planning constraints and made a positive contribution to its surroundings.

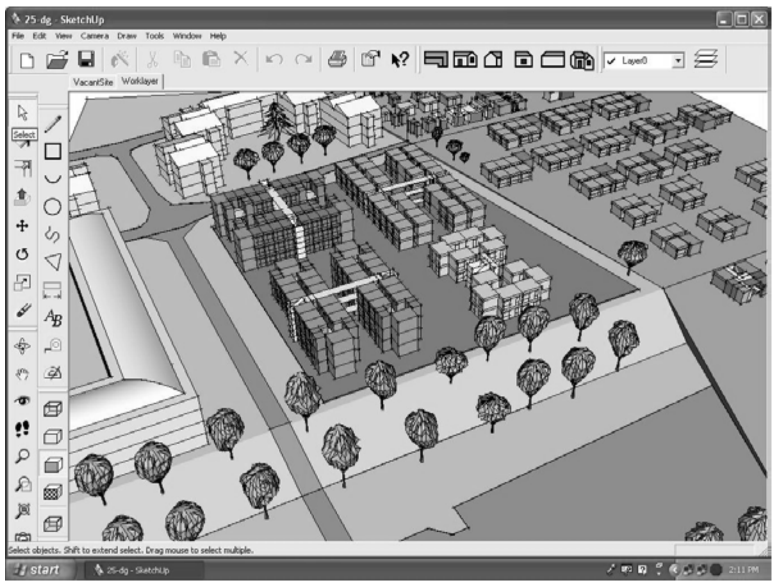
In order to assist the participants assess the cost implications of their actions, a spreadsheet-based costing model was developed which allowed them to see how their design performed in terms of the weekly rent that would be required in order to fund each of the room types they included in their scheme. This costing model was operated by the facilitator who entered the design data as the participant was working and then, once an initial design idea had been generated, would provide feedback on the anticipated renal costs of each of the room types provided. The participant could then modify the design in order to keep the costs within what they felt were acceptable limits.

One group (the physical group) was given a physical context model of the site along with traditional drawing and model-making materials. A range of study bedrooms were constructed prior to the experiment so that participants could choose which types they wished to include in their scheme and these also provided a starting point for the model that they were asked to build. Figure 1 shows the working arrangements for this group.



► Figure 1: Working arrangements for the physical group.

The other group (the digital group) worked with a digital context model, presented within SketchUp, on a laptop computer connected to a digital projector. In both groups the facilitator helped each participant by responding to any questions and by assisting with the physical model-building or with the computer modelling. The intention was not to provide instruction on how to use SketchUp, but to help participants work on their design and to visualise it as it emerged. However, if a participant showed a particular interest in using the software then appropriate assistance was offered. Figure 2 shows the SketchUp working environment for the digital group.



► Figure 2: The SketchUp environment used by the Digital Group.

Throughout each session a record was kept of the design as it developed and the participant was asked to complete a questionnaire in order to elicit information about their experience of the process. The resulting designs were also assessed in terms of the objective criteria that they displayed (plan efficiency, building costs etc) and a subjective assessment was made of the design quality of each of the eighty schemes. This was done by a panel of three independent architectural experts who focussed on the internal planning of the residential blocks, the planning of the site and the three-dimensional massing of the buildings. The experts came from a conventional architectural background and did not have any particular interest in digital design. If anything, they had a preference for using freehand drawing and physical models during the early stages of design. In order to make absolutely sure that there was no bias in their assessment, all eighty schemes were presented in a standard way. The final design by each participant in the physical group was translated into SketchUp and then all the designs, whether from the physical or the digital group, were presented as a random series of Powerpoint slides using a common template. Figure 3 shows a typical slide, which includes building plans plus three views of the scheme from standard locations.

◀ Figure 3: One of the 80 schemes presented in a standard way for expert evaluation.

3. RESULTS

3.1 Experience of the participants

In terms of the experience of the participants, there were relatively few differences between the two groups. As can be seen from Table 1, the results are very similar with both groups scoring highly on the ten-point scale that was used. Overall the digital group has a slightly lower average score (7.66 compared to 7.73), although it should be noted that with questions where there should be no difference to the scores, such as 'Evaluation of Project Briefing' or 'Evaluation of the Costing Package' where the experience was identical, the physical group gave higher scores than the digital group. This may indicate that they had a tendency to score more highly overall. The only question where there was a statistically significant difference in the scores was 'Ease of Visualising Design Form' where the digital group did better that the physical group, confirming the advantages that CAAD has in helping non-experts to understand the three-dimensional form of a building.

► **Table 1: Experience of participants during the design sessions.**

The results are based on a 10 point scale with 10 indicating the most positive response. There were 40 respondents in each group.	physical group mean	digital group mean	difference
Ease of visualizing design form	7.00	8.25	+1.25
Verbal expression of ideas	8.28	7.73	+0.55
Ease of manipulating the design	6.65	7.08	+0.43
Knowledge gained of student housing	6.88	7.20	+0.32
Level of reliance on facilitator	5.58	6.00	+0.32
Level of design cooperation	8.00	8.15	+0.15
Satisfaction with the final design	7.25	7.35	+0.10
Level of interaction	8.43	8.43	0.00
Satisfaction with the room setting	8.35	8.33	-0.02
Suitability of the tools used	8.18	8.15	-0.03
Evaluation of the costing package	8.70	8.63	-0.07
Own contribution to the design	7.83	7.75	-0.08
Facilitator's understanding of your ideas	8.75	8.38	-0.37
Visual and physical expression of ideas	7.70	7.23	-0.47
Enjoyment with participation	8.98	8.50	-0.48
Evaluation of project briefing	8.73	8.15	-0.58
Time available for design	6.63	6.03	-0.60
Ease of use of tools	8.10	7.40	-0.70
Average	**7.73**	**7.66**	

3.2 Design performance

Using the eighty schemes that were produced, a comparison was made in terms of how efficient the designs were. This was done by analysing the amount of circulation space (corridors, passageways, staircases and lifts) in each scheme on the basis that the higher the percentage of circulation space the less efficient a scheme was. Table 2 summarises the results.

► **Table 2: Percentage of circulation space in each scheme.**

	Percentage of circulation space			
	lowest	highest	Mean	std dev
Physical group	17.71	48.01	33.01	7.93
Digital group	17.48	41.75	23.25	4.79

There is a statistically significant difference between the two mean values. The digital group achieved a better ratio between functional and circulation spaces and thus, on this measure, produced more efficient buildings.

3.3 Costs

The indicator for cost was arrived at by dividing the capital cost of each scheme by the area of usable space. There was a statistically significant difference between the two groups with the digital group being the more cost effective (Table 3). These values represent the cost per square metre and are independent of the room sizes chosen although, inevitably, a scheme made up of many small rooms, each with its own en suite shower room, is likely to have a higher cost per square meter than a scheme with larger rooms. However, in practice both groups chose a very similar mix of room types, confirming that the higher cost is due to less efficient planning and building configuration.

Cost of functional area per square meter (GBP)				
lowest	highest	Mean	std dev	
Physical group	5333	6852	5973	431
Digital group	5209	6381	5523	240

◀ Table 3: Cost of usable area per square meter.

3.4 Professional evaluation

The professionals who evaluated the schemes were asked to rate each scheme on its internal planning, its site planning, and the building massing. A ten-point scale was used and an average score was also calculated for each scheme. The scores indicate that the digital group performed at a higher level than the physical group in terms of the architectural qualities of the schemes that were produced, with the result for 'internal planning' being statistically significant (Table 4).

The results are based on a 10 point scale with 10 indicating the most positive response. There were 40 respondents in each group.	**Digital group**		**Physical group**	
	mean	**std dev**	**mean**	**std dev**
Site planning	5.61	0.98	5.18	1.07
Building massing	4.91	1.06	4.89	1.05
Overall scheme	5.56	0.76	5.29	0.84

◀ Table 4: Summary of the professional evaluations.

With both groups 'internal planning' scored more highly than either 'site planning' or 'building massing'. This is understandable, given the time limitations placed on each design session. Much of the focus was on resolving the internal layout and, consequently, not enough attention could be given to the other two elements. Had more time been available, the site planning and building massing could have been more fully resolved and this is likely to have resulted in higher scores in these areas. However, it is unlikely that the overall difference between the two groups would have been affected.

4. DISCUSSION

In order to decide whether digital tools can offer significant advantages over their traditional counterparts, this research has looked at two main issues: the experience of participants and an assessment of the quality of the design outputs. It terms of how the participants felt about working with the two kinds of tools, the results for both were positive with the only real difference being that SketchUp made it easier for participants to visualise their designs. Given the unfamiliarity of CAAD software to this group of participants, this is an encouraging finding.

In terms of the objective indicators of performance, the digital group did better than the physical group. On average their designs were more efficient in their use of space and construction costs were also reduced, resulting in lower rental costs for the study bedrooms. There are a number of factors which could account for these differences. The increased accuracy of the digital tools means that the elements of a building can be manipulated and placed more precisely, thus helping to reduce unnecessary circulation space. The facility to copy, rotate and mirror parts of a building, or even whole buildings, means that a scheme can be generated more quickly, thus providing extra time for refining the design. One might assume that the availability of such tools would result in schemes that were less imaginative, but this proved not to be the case. The professional review panel rated the digital schemes more highly and unusual geometries, such as curved plan forms, were as evident in the digital group as in the physical group.

In the professional world of design computers have gradually moved from being used to automate existing tasks to become design tools in their own right [18]. However, in terms of interaction with the public, computers still tend to be used to present designs to clients rather than to allow them to engage directly in the design process. The normal way of working is for the architect to develop some design ideas and then show these to the client, often using a Powerpoint presentation, in order to get feedback. In such a situation more than one idea may be presented, particularly during the early stages of design, but as the design is refined the discussion focuses on more and more specific issues. Once the design is finalised the computer is then used to present the scheme in as attractive a way as possible in order to gain final client approval and subsequent planning permission. Those who advocate participatory design would argue that this process is fundamentally flawed as most professional designers have their own stylistic agenda which they impose on the client by restricting the choices on offer.

Participatory design, on the other hand, engages the client body in a much more open debate with the role of the designer being to tease out the needs and aspirations of the client while making all options both available and transparent.

When one observes how computers have affected the two ways of operating, it is clear that they have had a much more significant impact on traditional practice than on participatory design. However, the results of the experiment reported here indicate that there is considerable scope for developing digital tools to aid the participatory design process. Although, when introduced, SketchUp was a revolutionary product, the rest of the market is already catching up and we are likely to see an increasing number inexpensive and easy to use CAAD packages. The equipment used in this experiment was a standard notebook computer with SketchUp and Excel along with a data projector and screen. This equipment can be purchased for less than 2,000 USD and is standard equipment in most architectural practices. Cost is therefore no longer a significant barrier to this kind of technology and it is clear from the results of this experiment that it is sufficiently easy to use to make it accessible to non-experts.

As with any kind of participatory design, the role of the facilitator is critical to the success of the venture. Were this kind of technology to be adopted, the facilitator would have to become familiar with the software and that would require additional training. However, the potential advantages over traditional methods are considerable. Not only is it possible to manipulate forms very easily, one can also build up a catalogue of building types that can be used in different settings. The difficulty of storing and transporting physical models means that, at the moment, each design event tends to start afresh and there is no real opportunity to access previous work in its original form. A significant opportunity of learning from past experience is therefore being lost.

5. CONCLUSIONS

The work reported in this paper is the first stage of a longer project to investigate the use of digital tools in participatory design. It has demonstrated that modern CAAD software has reached the point where it can move out of the design studio and be used to engage more directly with the public. The experiment used a standard version of SketchUp with no customisation but, even so, it proved to be a useful tool that helped non-experts to work successfully on a complex design with relatively little assistance from the facilitator. The way in which the project was set up meant that designs were not being constructed from scratch, rather pre-built rooms and groupings of rooms were being amended and then assembled. The basic commands which allowed elements to be moved, rotated, mirrored and stretched proved to be the most useful and the workspace made it relatively easy for the participants to work directly in three-dimensional space in a way that was analogous to working with a physical model.

The next stage is to move from the laboratory to the real world and to test these tools in live design events. In parallel with this, SketchUp will be customised in order to develop the user-interface and focus on those commands and facilities that are more appropriate to this kind of setting. Although the use of a spreadsheet in parallel with the design software was an expedient way of costing the schemes once they had been developed, it would be much more effective to have this feature built into the CAAD software. The intention is therefore to use SketchUp's Ruby programming language to implement these features and thus tailor the software to the participatory design environment. The use of more innovative display and interaction devices will also be investigated in order to create a physical environment that is more conducive to group working.

Although we see considerable opportunities in using computers to aid participatory design, we are not suggesting that they should replace all other media. Each particular medium has its own characteristics and existing strengths should not be lost. Physical models have a presence that is very engaging and they are an excellent way involving groups of people in a discourse. However, computers offer additional ways of exploring design issues and should therefore be considered as an option to provide a richer environment for participatory design.

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