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Computer Aided Design: Implications for pupil attainment and assessment

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Abstract

Previous research has established that, at the very least, the introduction of CAD into design practice led to the better communication and presentation of ideas in the form of high quality outcomes. It recognised that the predominant use of CAD as a means of output is likely to be encouraged by its ability to directly support separate points of assessment rather than focusing on the act of designing itself.

This paper develops on the previous research undertaken by means of a web administered survey and highlights a strong relationship between CAD implementation and an increase in pupil attainment. The paper suggests CAD allows pupils to consistently meet a level of quality, manufacture and accuracy that is well rewarded by some specific points of assessment. Teachers observed an increase in the percentage average A*-C grades of around 10%.

The paper reflects on a number of specific case studies which illustrate that despite the emphasis on final outcome it was apparent that CAD was contributing to not only the general quality of pupils' design work (in terms of presentation etc) but additionally the quality of design development.

Key words

CAD, CAM, attainment, assessment and design

Introduction

Digital design and the notion of computer aided 'designing'

Computer Aided Design (CAD) and manufacture is now firmly established as an integral part of design and technology education. The success of such initiatives as CAD/CAM in Schools (which now includes most English Secondary schools) has provided design and technology researchers with a period in which to reflect on current practice and guide the discipline's future direction. Whilst it is well established (Fraser and Hodgson, 2006) that CAD has significantly altered the methods that pupils of design and technology education adopt for sketching, rendering and model making; the extent to which the formulations of design and technology subjects (in particular their assessment) have evolved to encapsulate these issues is relatively unclear.

Within industrial practice, the role of CAD is no longer viewed merely as the integration of a new tool into the 'conventional' notion of design. Digital Design and the notion of 'computer aided designing' is now firmly established as a means by which design and the activity of designing are undertaken (Oxman, 2006).

As a result, industrial design practice has been seen to adapt to the changing nature of the methods adopted by its' designers and embrace these new technologies as a genuine means of proceeding with design problems. The significance of this evolution is such that Yang et al (2006) suggest it has altered the value of the fundamental skills required for an industrial designer. Oxman (2006) states that inevitably there exists a need to re-formulate the fundamental concepts of design theory to consider their appropriateness in light of the increased use of digital media in the activity of designing. Moreover, if, as Sethia (2001) notes; that the changes in the industrial design profession are likely to have stimulated some significant transformations in design education and, as Kauffman (1998) suggests; that the development of design education is likely to be have been considerably slower than that of its industrial counterpart, it is probable that such an agenda is worthy of address within an educational context.

Assessment and its relationship with CAD implementation

Previously, Hodgson and Fraser (2005) identified that the predominant use of CAD was as a means of providing design 'output' (images, artefacts, etc) rather than making any significant contribution to the activity of 'design'. That is not to say that manifestations of design thinking (in the form of images, artefacts etc) cannot provide useful contributions to iterative design development, but that the term 'output' (in this paper) refers to the end product of such design activity and is principally employed for the purposes of assessment.

Since that time, research has established that the use of CAD is likely to be encouraged by its ability to support separate points of assessment rather than the activity of designing itself (Fraser and Hodgson, 2006). This is unsurprising as, in the authors' opinion, there is a tendency for designing activities in schools to be focused on snapshots of assessment, often to the detriment of the holistic design activity.

However, if evidence from earlier research is considered, it is apparent there are likely to be additional incentives for applying CAD to school based design work in such a manner. For example, teachers suggested that CAD, in the form of high quality output, allowed pupils to consistently achieve a high level of accuracy and quality in their final manufactured outcome. Moreover, that this outcome better met the needs of assessment criteria that had arguably failed to evolve to encapsulate the changing nature of design and technology (Fraser and Hodgson, 2006). The extent to which the anecdotal evidence previously collected accurately reflects the opinions of the wider population of interest was relatively uncertain. What was certain, was that at the very least it may go some way to explaining the predominant use of CAD as a means of output (identified by Hodgson and Fraser 2005) and why the perceived benefits of CAD are often related to project-based making and manufacture rather than making any considerable contribution to design development and subsequently a 'better design'.

Therefore, the predominant adoption of CAD as a means of generating output and its relationship with pupil attainment and assessment are discussed in this paper. The paper aims to highlight to what extent CAD is adopted as a means of generating manufactured and other outcomes for the purpose of meeting specific points of assessment and also as a design tool for design development. Whilst this paper offers no opinion on the impact this might have on teaching and assessment of design and technology, it highlights an agenda for research in light of the increased use of digital media (specifically 3D CAD tools) in design education.

Method

Towards an understanding of the relationship between CAD implementation and pupil attainment

In order to better understand the relationship between CAD implementation and pupil attainment it is important to establish the extent to which the evidence collected in earlier research is accurate and more importantly reflects the opinions of the wider teaching population. In order to do this a web-based survey was designed and distributed to 310 heads of design and technology departments nationally. A copy of this survey can be found at: www.alisterfraser.co.uk/survey

Teachers were asked not only if they felt CAD/CAM had had any direct influence on recent pupil attainment but additionally the extent to which they felt this had influenced the manner in which CAD was implemented. To answer this a statement generated from a summarised series of case studies offered by participants of previous research was posed. This was then further scrutinised by inviting response to a series of questions

which addressed the same issues indirectly. The statement chosen for this purpose was:

"Pupils consistently meet a quality of manufactured outcome, engineering drawing and accuracy of manufacture that is rewarded by assessment criteria. As a result the predominant use of CAD/CAM for my pupils is as a means to achieve these assessment points."

Participants were asked to record their strength of feeling to the statement posed and record their response on a five-point Likert scale. Accepted content values ranged from strongly disagree to strongly agree, thus, a total numerical value for each response could be calculated and opinions represented quantitatively.

Participants were also asked to offer an estimated % average A-C grade both post and prior to CAD implementation. It was requested that this information only be given if they felt they could substantiate it at a later date. Of the participants that responded 63% felt that the information they offered could be substantiated. Therefore, the remaining 38.6% of responses have been negated from further analysis. The results of these questions are shown in Tables 1 -4.

Participants were asked to offer some specific examples in which aspects of CAD/CAM implementation had significantly contributed to any improved pupil attainment. The qualitative opinions expressed were recorded and coded into a series of domains. These domains were generated from a series of responsive criteria (i.e. directly from the survey data and concurrently at the time of analysis) rather than any pre-conceived or pre-determined notion of what the data may contain. The domains were categorised into areas that reflected a wider activity or topic. By recording the frequency at which participant data was coded for each of these domains the qualitative opinions expressed are recorded quantitatively and analysed accordingly. The results of this analysis are shown in Table 5.

Results

To what extent do you agree with the statement below?
"Pupils consistently meet a quality of manufactured outcome, engineering drawing and accuracy of manufacture that is rewarded by assessment criteria. As a result the predominant use of CAD/CAM for my pupils is as a means to achieve these assessment points."

Response	Value (%)	Respondents (No.)
Strongly Agree:	21.05	16
Agree:	55.2	42
Not Applicable:	2.6	2
Disagree:	21.05	16
Strongly Disagree:	0	0

Table 1: The extent to which respondents felt the following statement reflected the role of CAD within their department

Has pupil attainment (specifically GCSE or 'A' level a-c grades) improved since the introduction of CAD/CAM into school based project work?

Response	Value (%)	Respondents (No.)
Yes	90.7	69
No	8.3	7

Table 2: Number of participants that felt attainment had improved as a direct result of CAD/CAM

Which do you think is the most contributing factor to any increase in attainment?

Response	Value (%)	Respondents (No.)
CAD	28.9	22
CAM	15.7	12
Both	55.2	42

Table 3: What participants felt was the most contributing factor to any increase in attainment

36.8% of respondents felt they could not substantiate their claim therefore these responses have been disregarded. Therefore of the remaining 62%.

	Prior (%)	Post (%)	(%)
Average A- C Grade	64.04	73.95	
Average Percentage increase			9.91
Schools recording no change			1.52
	High (%)	Low (%)	(%)
a-c grades recorded	100	35	
Highest % increase recorded			30
Lowest % increase recorded			-5.0

Table 4: Participants estimated A-C grade % average (post and prior to the implementation to CAD/CAM)

Discussion

The predominant use of CAD and its link to assessment

Of the 310 people questioned 78 responses were recorded. The responses to the survey show that a significant proportion (76.25%) agreed or strongly agreed that the predominant use of CAD as an output was as a result of its ability to meet assessment criteria in the form of quality and accuracy of manufactured outcome. For example, whilst only four participants noted that its contribution to design development had any further impact on pupil grades, 54 participants identified the single most contributing factor of CAD/CAM to be its general impact on the 'quality' and 'accuracy' of the final manufacture outcome. Also 72 Participants cited the increased quality of both presentation and manufactured outcome as being the main advantage of CAD/CAM in school-based designing.

Of the participants that were asked to offer an estimated average A*-C grades post and prior to the implementation of CAD/CAM only 62% felt that the information they offered could be substantiated with relevant data if required. Therefore, the remaining 38% of responses were not included in further analysis. Of the 62% of responses recorded, the average A*-C grade was estimated to have risen on average 9.91% from 64.04% to 73.95%. In each of these cases teachers felt this increase could be attributed to the implementation of CAD/CAM into their curriculum. In some cases the percentage increase in A*-C grades recorded was as much as 30%.

Better designers or designs better rewarded by assessment?

It is apparent from the results that a significant proportion of teachers felt the implementation of CAD was as a result of its ability to meet assessment criteria and as a result had a direct influence on pupil attainment. The extent to which this increase in pupil attainment is attributed *solely* to CAD in the form of high quality outcome or has additionally had some impact on the quality of design development is, at this stage, undefined.

For example, the predominant adoption of CAD as a means of solely obtaining quality outcomes for the purposes of presenting final designs and assessment (i.e. images, artefacts etc.) may viewed as a naïve use of CAD (as it undervalues the potential for CAD in the holistic design process) it is apparent that this assumption, in itself, may be somewhat naïve. It seems unlikely that despite the principle adoption of CAD for the purpose of producing design 'output' that it will have made little or no contribution to design development. What remains to be established therefore, is the extent to which the use of CAD in school based design work not only contributes to designing but more importantly whether its application results in better designers and designs, or, as suggested, merely outcomes which are better rewarded by assessment criteria.

Interestingly, Dearden,(2006) states that within industry at least, the use of digital technologies is increasingly common both as the outcomes of designing and within design activity itself. Is this necessarily the case within school based design?

Computer aided design or computer aided outcome?

Some case study observations

In order to better understand the role of CAD in school-based design (specifically its contribution to the act of design and development) case studies were collected for two purposes. Firstly, to further support the earlier information relating to CAD implementation and assessment but additionally to illustrate any additional contribution of CAD to design development not communicated by the statistical nature of the initial research. These case studies supported that teachers have generally observed pupil attainment as continuing to improve with the increased use of CAD, CAM and RP integrated into pupils' coursework and in this manner supported the data presented earlier in this paper. For example, one such teacher stated that:

"In the last year alone 37 more pupils integrated CAD/CAM and Rapid Prototyping technologies into their GCSE coursework than the year previously and there was a 10.7% rise in A-C grades."*

The teacher in this instance was also able to provide similar evidence at both AS and A2 level with the average increase in A*-C grades being 17.2%. Also as identified earlier, teachers generally recognised that the single most contributing factor to this increase in attainment was considered to be the quality of final manufactured outcome. However, what is interesting is that within the case studies teachers did not only identified an increase in just the quality of the final outcome but also within pupils' work generally and moreover, within aspects of design development.

"The overall quality of the work has improved through the addition of many new skills and techniques, but the biggest improvement has been the quality of development and final manufactured outcome, which is mainly through the advanced use of CAD, CAM and RP."

Domain description	Respondents (No.)
Aid to Manufacture	38
'Accuracy in manufacture'	20
Manufacture more complex products	16
Better appreciation of benefits of accuracy	2
Aid to Design/Development	42
Better communicate ideas	14
Better visualise ideas	10
Drawing no longer restricts development	8
Encourages development	8
Encourages/allows effective testing and evaluation	2
Quality	72
Better quality of presentation	30
Better quality manufactured products	34
Better quality of engineering drawing	8
Other	24
Better grades	4
Reflects industrial Practice	2
Motivation	18

Table 5: What is the most significant contributing factor to any increase in attainment attributed to CAD/CAM? (Please give some specific examples.)

On further consideration, the data collected from the original survey supports this (see Table 5). Much like the case studies, although in this instance somewhat indirectly, teachers suggested that perhaps CAD *was* additionally making a contribution to genuine design development.

Interestingly, a number of teachers stated that 'quality' in presentation and final manufactured outcome additionally led to the ability to better communicate and visualise ideas. However the data does not make explicit the extent to which this better communication and visualisation of design ideas contributed to stages of iterative development rather than simply the better 'presentation' of final design outcomes. It is certain that CAD's strong relationship with outcome and assessment has influenced its implementation but to what extent has that inadvertently influenced the quality of design?

At the very least, teachers noted that in some instances Computer Aided Design meant drawing capability was no longer a restriction to pupils in the process of designing. Inadvertently suggesting that the use of CAD as an output is perhaps synonymous with at least *some* contribution to the quality of *design* in addition to the quality of *outcome*.

The significance of CAD/CAM's potential to contribute to the activity of designing (despite its principle adoption as a means of providing design output images, artefacts etc) is not to be underestimated. However, perhaps as a result of the strong relationship between CAD as a means of producing quality outputs and an increase in pupil attainment brought about by CAD's contribution to assessment points it would appear that Computer Aided *Design* is undervalued.

That is to say that CAD/CAM is not so much making *no* contribution to school based *designing* but more that its application reflects the general emphasis for school based design activities in general to be focussed on snapshots of assessment, rather than the holistic design activity.

Conclusions

It has become apparent that the predominant uptake of CAD/CAM as a means of generating output (images artefacts etc) is as a result of its ability to directly support points of assessment rather than help to develop *better* designs.

A significant proportion of teachers observed that CAD/CAM was positively impacting pupil attainment with an increase in

the percentage average A*-C grades of around 10%. Teachers identified the single most contributing factor of CAD/CAM to this increase in pupil attainment as being its general impact on the 'quality' and 'accuracy' of the final manufactured outcome. Despite the teachers opinions offering an insight into the issues surrounding Computer Aided design and its relationship with assessment, the authors feel a broader survey based on comprehensive *statistical* data should still be encouraged.

Even though there exists an emphasis on final outcome it was apparent that CAD, was potentially contributing not just to the overall quality of pupils design work (in terms of presentation etc) but additionally the quality of design development. For example teachers noticed that the introduction of digital media in the process of designing meant the restrictions imposed on some pupils ability to communicate ideas through more traditional techniques such as sketching were no longer as significant.

What remains to be established therefore, is the extent to which this implementation of CAD/CAM (regardless of whether or not its implementation is influenced by assessment) has any additional bearing on the quality of the design as opposed to just the design outcome itself.

What is certain, and what this paper has established, is that despite the potential for CAD to contribute to the quality of design (in earlier stages of iterative development) it is likely that CAD implementation will remain focussed on school based making and manufacture. For example, it is likely that the potential contribution of CAD to design is likely to not be considered as significant as any contribution to an increase in pupil attainment.

What remains to be established however is, that in so doing, does CAD inadvertently have any additional impact on the quality of design despite its principle adoption for the purposes of meeting points of assessment? This is the point of continued research at Loughborough University.

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