DEVELOPMENTS IN TEACHING APPROACHES:
“THE UNEXPECTED BENEFITS OF AN INTEGRATED CAD/CAM BASED MODELMAKING STRATEGY”

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ABSTRACT
This paper will examine several unexpected dividends from the implementation of broadly implemented and integrated CAD/CAMM model making strategy. It first discusses the expected outcomes of implementing CAMM on a broad basis: high investment cost, high fidelity facsimile models, integration of Virtual and Actual 3D output, improved Health & Safety, higher speed model making output, steep learning curve (staff & students) and high running costs.

The second section of the paper discusses the actual results of implementing CAMM as a standard educational tool within the PDP.

The third section of the paper reveals some surprising and unexpected windfalls of CAMM implementation and uses case studies to examine the benefits they have brought to education at undergraduate level. In conclusion, the authors discuss what was learned and achieved by the adoption of an entirely new and radically different approach to design education.

Key words: Computer supported design education, Model making, CAD, CAM, Knowledge, Transferable, Holistic, Structure, Integration, Product design process, Learning, Modules, Curriculum, Education
1 INTRODUCTION: THE CAMM IMPLEMENTATION MODEL

Like many universities in the 1990’s UWIC’s model making strategy was based on the traditional soft modelling using foam and card augmented with hard wooden facsimile models that were either carved by hand or shaped using manually operated machine tools. Although very time consuming, this strategy had served the needs of the product design students well over the twenty years that the course had been in existence. This traditional product design process [X] used on the undergraduate programme at UWIC evolved to use 2D Computer Aided Design as a means of producing accurate BS888 compliant drawings in order to capture design for manufacture intent and to inform the manufacture of facsimile models.

By the end of the 1990’s this strategy was beginning to create significant difficulties. An increasing focus on Health & Safety had led to limits being set on the number of students allowed to use the workshop at any one time. This was exacerbated by the post-Deering HE environment with significant increases in the number of students.

At the same time a change was noticed in industry practice in that it was becoming increasingly common for designers to take advantage of the high tech rapid prototyping technologies that were emerging. It was also becoming increasingly common for manufacturing companies to build injection moulds either via direct CNC machining or by using CNC spark erosion techniques, where tools were produced direct from 3D CAD data, obviating the need for technical specification drawings.

As the ability of mid range 3D CAD programmes advanced though the second half of the 1990s it became clear that it was time to consider adapting the design process to create 3D CAD based “virtual prototypes” in order to more fully and accurately capture the design intent. Once a virtual prototype is available it becomes relatively easy to progress the design to the next stage i.e. that of rapid prototyping thus integrating the activities of real and virtual prototyping.

There was an additional factor: Traditional model making using manual machine tools is a very highly skilled activity that requires many years of practical experience. Clearly the time taken to achieve this skill level precludes most students from achieving a very high standard of model making during their three years as an undergraduate.

Rapid prototyping machines on the other hand are generally capable of producing very accurate reproductions of virtually any given design independently of the model making skill of the operator.

It was therefore expected that if the students were to exchange the over-ambitious aim of becoming skilled traditional model makers for that of becoming a rapid prototyping machine operator then the quality of facsimile models must improve to the near perfect levels of reproduction that these machines are inherently capable of.

It soon became clear that a new strategy was required at UWIC if we were to meet the needs of a growing student population, increasing emphasis on health and safety, and
addressing the changes in working practices in the product design industry while maintaining and even increasing the level of 3D interaction the students needed in order to study the subject effectively.

It was clear from the outset that there were a number of significant benefits to be gained by adopting a Computer Aided Model Making (CAMM) strategy such as the potential for high-fidelity facsimile models. These advantages however, were seemingly balanced by a number of significant disadvantages not least of which were the very high capital investment cost and steep learning curve for staff & students.

In addition there was a strong desire to maintain the well known benefits of concept sketching and soft modelling in the form of sketch modelling by hand.

1.1 UWIC’s Approach to the problem – the potential routes.

Initial investigation at the start of the millennium revealed that there were a growing number of rapid prototyping machines on the market that could facilitate an integrated CAMM methodology at UWIC.

The technologies they used were divided into two distinct approaches which may be summarised under the headings of “material on” and “material off”.

The “material on” group included Stereo Lithography, FDM, FDS, SLM, LOM, etc. Whereas the “material off” group consisted of various types CNC machine tools with a main focus on multi-axis milling machines.

The “material on” group generally had the advantage of being relatively easy to use while the “material off” group were generally thought to produce more robust prototypes.

Machines in the “material on” category ranged in purchase price from approximately £30,000 to £500,000, while those in the “material off” category ranged from £**** to £****. Materials and running costs also varied widely. Generally speaking, “material on” is more restrictive, with shelf lives for many materials, recycling frequently an issue and storage of light, time or moisture sensitive materials complicating matters further.

In the light of these factors the decision was made to purchase “material off” machines.

There were a number of expected ramifications from this decision.

2 EXPECTED RAMIFICATIONS

2.1 High Investment Costs
The expectation had been that investment costs would be high enough to force a very gradual change. This problem was solved by the purchase of low tech. CNC routers that could be purchased in high enough numbers to serve large cohorts of students.
2.2 Improved Safety
Statistics show [XX] that the use of power tools and machine tools is inherently unsafe (or carries at least some risk of injury to the operator?). Rapid prototyping machines on the other hand tend to operate automatically with any potentially hazardous moving parts hidden being safety screens that are protected by safety interlocks. They therefore tend be inherently almost completely free of risk of injury to the operator. This allowed the machines to be operated safely without staff presence. Twelve hour, seven day access is now permitted.

2.3 Steep Learning Curve
A well established down side to the introduction of any new computer based technology is the steep learning curve that must be climbed before the new technology can be used to it’s full potential. In UWIC the problem was tackled by ensuring students had access to comprehensive guidance notes that they could refer to, backed by the use of sound and video files that reinforced various points. Students were able to constantly refer to these notes and files, so increasing the rate at which they were able to problem solve. The method by which these notes and tutorial were made was via the Programme’s own Virtual Learning Environment, The Virtual School (Gill & Coward, 2000)

2.4 High Running Costs
A quick survey of the prices quoted by rapid prototyping bureaux suggested that the operating costs of rapid prototyping machines was significant and substantial. This was clearly of concern to an undergraduate product design programme with a small budget.

3 ACTUAL RAMIFICATIONS
This section of the paper discusses the actual results of implementing CAMM as a standard educational tool within the PDP.

3.1 Investment cost
The initial investment cost was minimised by the choice of technology selected. It was decided to attempt to minimise the cost of investment by initially purchasing only one small inexpensive 3-axis CNC router. This machine was approximately one tenth of the cost of the nearest equivalent material on rapid prototyping machine at the time of purchase. Following the successful introduction of this machine an number of other machines were purchased over the next five years.

3.x Improved quality of design
Experience has shown that the quality and amount of detail design work undertaken by the students using RP as part of the design process has increased significantly compared to that produced using the traditional design process.
It was found that the students were able to spend more of their time engaged in the study product design theory and actual design practice because they were released from the burden of having to acquire the skills of using manual machine tools to make models.

3.2 Improved quality of facsimile models

The quality of facsimile models has increased significantly since the introduction of CAMM. This is clearly illustrated by the photographs below…

The first two show the typical output of the traditional manual machining approach…

![Figure 1: A model glue gun model designed to suit manufacture by turning and milling.](image1)

![Figure 2: A model glue gun designed to be made by bandsaw and hand finishing.](image2)

The following photographs show the much improved output from a similar project but using the new CAD-CAMM approach.

![Figure XX:](image3)

![Figure XX:](image4)

As can be seen from these images the simplified forms shown in figures XX and XX have given way to more sophisticated, fluid, compound forms ….
One distinct advantage of his approach over the manual method is that is very much easier to make a second model or even a range of similar models each illustrating a design variation.

3.3 Integration of Virtual and Real Prototyping

3.4 Improved Safety
The safety record of the machines in question is excellent with no accidents attributable to these machines having been recorded in the five years since their introduction.

3.5 Steep Learning Curve
As expected there was a steep and difficult initial learning curve for the staff before the first machine could be used productively. After approximately one year it was agreed that a step by step user manual should be created that would guide anyone through the generic manufacturing processes. This guide has been refined over the years and is now used as the de facto standard that all staff and students adopt when learning to use the CNC machines for rapid prototyping. This guide is available on the department’s VLE (The Virtual School) where it is augmented by a number of supporting documents together with a series of short video clips describing the basic machining process.

3.6 Running Costs
The running (material) costs for the CNC machines that were selected has proven to be quite reasonable and is comparable with the manual prototyping methods. The material of choice for general purpose rapid prototyping of plastic parts is known throughout the CNC machining industry as “tooling board” and is a proprietary high density closed cell, foamed polyurethane-based material. This material produces excellent results and is sufficiently robust to simulate a wide range of proposed materials.

The cost of tooling board compares well with the cost of the more traditional Jellutong a specialised use close grained hardwood which was extensively employed when making models via the traditional manual route.
4 UNEXPECTED BENEFITS

This section of the paper reveals some surprising and unexpected windfalls of CAMM implementation and uses case studies to examine the benefits they have brought to education at undergraduate level.

4.2 Elimination of “Design for Model Making”

One of the major unexpected benefits on adopting an integrate CAD-CAMM methodology was the elimination of the activity of “design for model making” [ref paper 1].

The elimination of this step produced an immediate and significant emancipation of the students design ability.

No longer was it felt necessary to constrain the design of the model to be more easily made by the standard manual manufacturing techniques that were readily available.

…….. Freeing up design ……

4.2 Reinforcement of Design for Manufacture

Limitations of 3-axis CNC are analogous to those of injection moulding i.e. draft angles and no undercuts ….this helps to ensure that the students full consider design for manufacture ….blah blah etc

The following Photo sequence of of a glue gun prototype shows the extensive internal detailing that fully captures the designers intended design for manufacture detailing.
4.3 Fully functional prototypes

Another unexpected benefit of the CAD-CAMM approach is that it has enabled the creation of moulds that can be used to cast electrometric products. (include example maybe photo of rubber watch thingy and or soap project)
CONCLUSIONS

In conclusion, the authors discuss what was learned and achieved by the adoption of an entirely new and radically different approach to design education.

The implementation of a CAD-CAMM strategy as an integrated part of UWIC’s product development process has been very successful indeed.

In last years external examiners report it was declared that this strategy “sets national standards” (check quote)

Accidents are down.

Workshop throughput is up.

Quality of manufacture is up.

Design for model making has been eliminated.

Design for manufacture has been enhanced and reinforced.

The quality of facsimile modelmaking has been significantly improved.

Working prototypes have become an everyday reality.

CAD-CAMM mould making is a bonus – elastomeric stuff, aluminium casting and vacuum casting etc.

Paul & Steve are all round good eggs and frightfully decent chaps.
REFERENCES


