

Trends and Challenges in Sport Science and Engineering Related Technology Education at Surf Science and Technology: Researching Surfboard Making Activity *

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Abstract: The paper presents the results obtained from teaching, learning and research associated with Surf Science and Technology (SST) course taught at the South West Campus of Edith Cowan University. The main topic discussed is Teaching and Learning with the Surfboard Making. It looks at a group of recent second year SST students who, after acquiring the necessary scientific and technological skills related to the production and performance of surfboards, were asked to design and produce their own surfboard during the Surf Equipment, Design, Materials and Construction Course. The first part of this paper describes briefly the most important steps in the surfboard making procedure. It is then followed by a series of photographs showing the SST students in various surfboard shaping and laminating activities. The next section provides some examples from teacher-student interactions in terms of individual approach and the group as a whole. It was realized that each student aimed to create a surfboard that would best suit his or her surfing skill. This resulted in the production of various surfboards that differed in the length, shape, weight, appearance, the number of fins, fin design and the surfboard/fin material. The results were analysed using a comparative statistical method that allowed determining the relative importance of each qualitative criterion with respect to other criteria associated with surfboard design features and performance. Following the discussion of the results, there are main conclusions highlighting the outcomes interesting from both pedagogical and professional practice perspectives.

1. Introduction

There is a strong bond between surfers and their surfboards. Traditionally, the surfers are looking for any improvements in surfboards that would suit their style and enhance their surfing performance. Generally, the performance is dictated by the surfboard's geometrical features and materials and the ability of an individual to surf.

1.1. Surfboard's Geometry and Materials: A brief history

Surfboards have been made for several hundred years. Some few rare 200-year old wooden surfboards are held at Honolulu's Bishop Museum [1]. These earliest surfboards were, doubtless, of poor quality. History has indicated that the key technological improvements in surfboard constructions went through numerous trial-error-success experiments. According to source [2] some early Hawaiian long-boards produced around 1830's were made from 'hard' wood, were around 4.5m long and about 0.5m wide, and weighed approximately 50kg. Consequently, they provided good buoyancy but very low manoeuvrability. By the 1920's, Duke Kahanamoku had introduced long-board surfing to Australia and California [2, 3]. The boards used at that time were made from soft-light balsa and were about 3 metres long. Their stability and turns were controlled by rails and foot drags, respectively. The rails were rounded and this geometrical feature was responsible for creating the sideways forces that were sufficient to keep the board on the wave [4]. Around 1930's an amateur surf equipment inventor [5] Tom Blacke connected a boat keel to his surfboard and realised that by doing so he improved the stability. The keel acted as a fin and helped to hold the board in the water. Experiments with fins and surfboards continued. It was found that with a fin attached to the

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surfboard the rails can be square and sharp. In 1950's fibreglass and polyester resins forced their way into surfing industry. In 1960's the surfboards became to be produced from polyurethane foam blanks shaped and covered with water resistant fibreglass resin coat. Until mid 70's the trend was to have the sharp and 'hard' resin edges along the rails [4]. According to the same source [4] those types of rails did not cope well with incident cross flow. A compromise was found by making the square 'hard' rails near the tail of the board to decrease the drag forces, and having more or less rounded rails further forward to the surfboard' nose to cope better with incident cross flow. Evolution continued with introduction of twin fin design at the end of 1970's and the three fin design (thruster) at the beginning of 1980's. The thruster became a very popular design and it is believed that about 90% [5] of the world's boards are equipped with three fins.

There is a continuous evolution in surf science with respect to surfboards. Nowadays there are 5 main types of commercially made surfboard designs suited for different types of wave riding, namely Type "Fish" surfboards for small waves; Type "Short" – high performance- surfboards for bigger waves; Type "Mini-mal or Fun" surfboards for beginners; Type "Mal or Long" (Malibu) surf boards for small waves and easily paddling, and finally Type "Gun" for big wave riding. Source [6] suggested that the above boards vary in design, geometrical features and number of fins. Consequently each surfboard is a unique output of designers and shapers.

Currently the South West Campus Bunbury at the Edith Cowan University (ECU) has a number of young people studying, exploring and researching the scientific and technological aspects associated with the production and performance of surfboards. Over the course of several units the students are taught to understand materials, design features, quality management, standards and safety engineering. After acquiring the necessary skills, they are encouraged to design their own surfboard, shape it, manufacture it and test it. In an open learning environment they feel free to combine research science with hands-on skill and use their ideas. This approach produced a variety of different surfboards, examples of which are shown in the following section of this paper.

2. Surfboard Making Activity at ECU

Figure 1 and 2 are sets of photographs showing various examples of students' work involved in surfboard making activity. These photographs are presented in a sequence that shows individual stages in a production flow charge. The photographs in Figure 1 relate to the shaping process and they show the individual sub-operations and their role and tools used in producing the main surfboard design features. The photographs in Figure 2 relate to the laminating process and they show a typical sequence of operations used in hand laminating of surfboards. The photographs were taken during the practical work in surf science shed in the second semester of 2004.

 <p>(a) Drawing the shape of the surfboard on one side of the blank.</p>	 <p>(b) Cutting the shape.</p>	 <p>(c) Cutting and trimming the tail and nose.</p>
 <p>(d) Using a sur-form to plane the shape</p>	 <p>(e) Using a cardboard paper to make a template of the planned shape. Offsetting it along the stringer.</p>	 <p>(f) Repeating the procedures (2) and (4) to get the rough shape of your surfboard.</p>

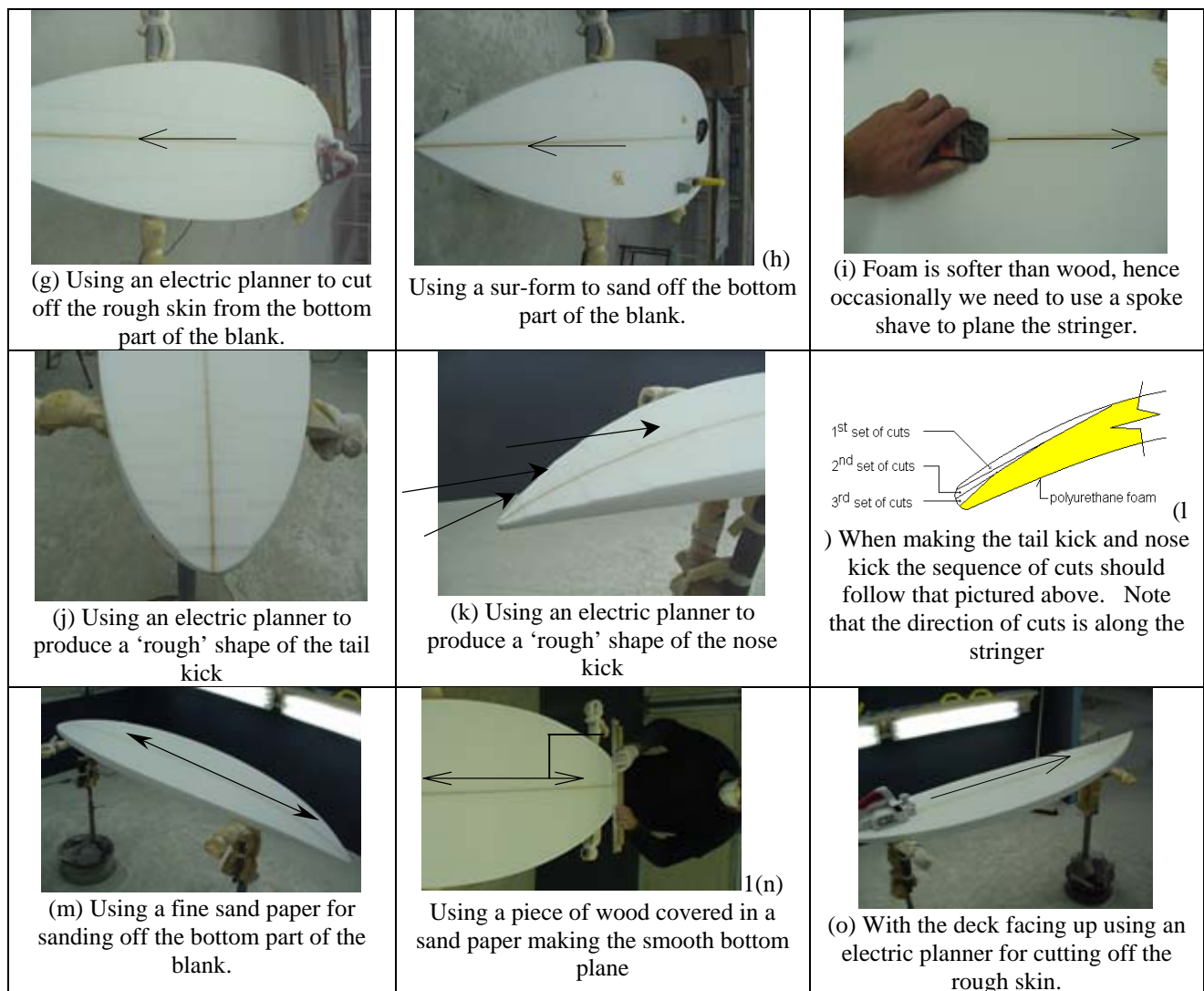
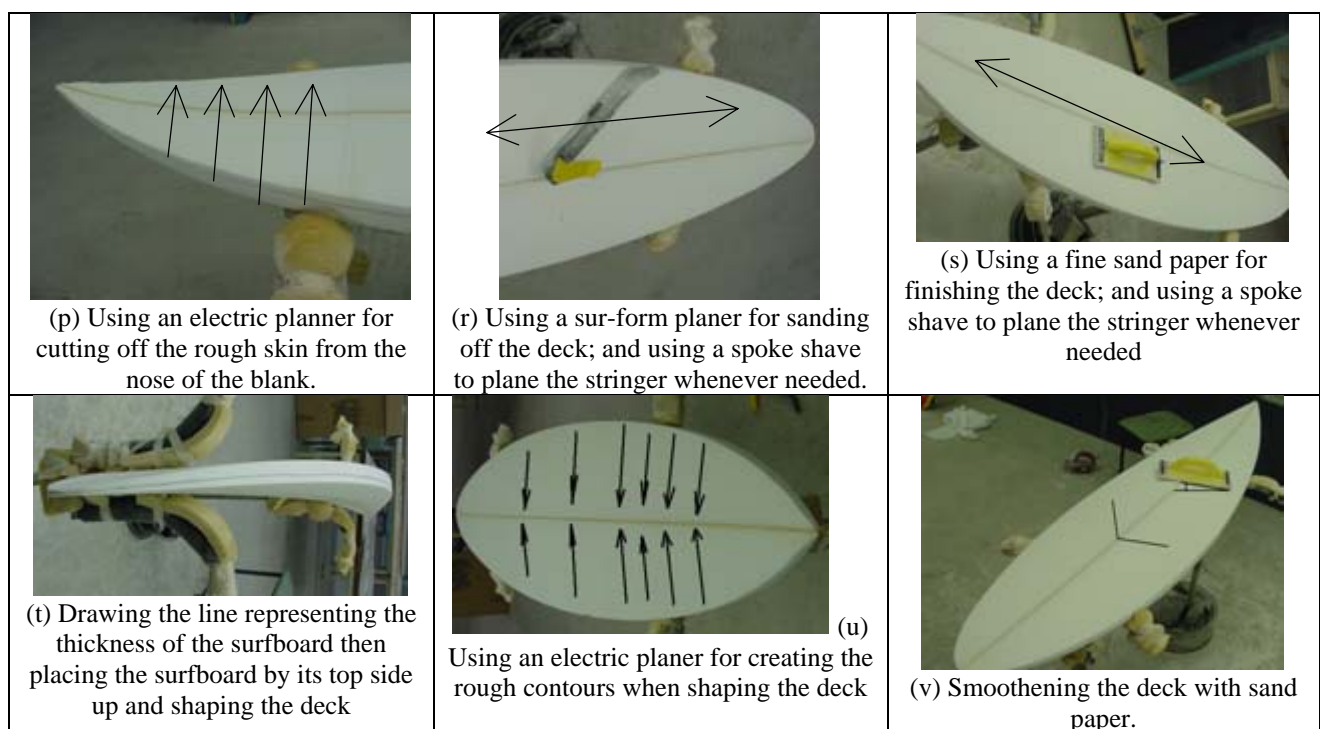


Figure 1 Photographs showing the production sequences of shaping procedures for various surfboards. Photo courtesy: Audy J. – lecturer.

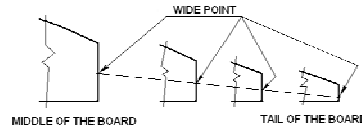




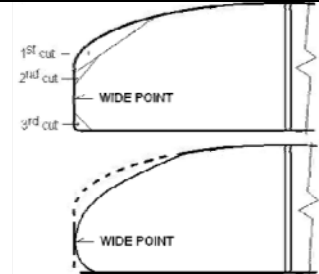
(w) When shaping the deck it is necessary to make long continuous movements with a hand that holds the shaping tool and check possible bumps with another hand.



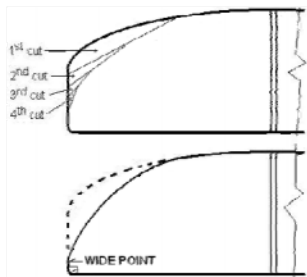
(x) Drawing the lines representing the dimensional features of surfboard rail(s).



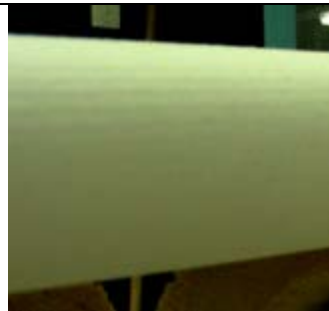
(y) Trimming the edges using surf-form planer and/or sand paper planer



(z) This picture shows a process of shaping the rails along the middle part of the board.



(q) This picture shows a process of shaping the rails along the tail of the board.



(aa) Shaping the rails step by step side by side is needed in order to keep the symmetry.



(bb) Using a shaping gauge ie 'dragon skin' the edges of rails are rounded and trimmed.



(cc) Long gentle movements with rounded gauge are used to make the rounded rails.



(dd) when doing tail it is necessary to have the rounded edges at the top, but the bottom must stay sharp.



(ee) Misery likes company if the foam is chipped during shaping there is no need for panic



(ff) Q-cells mixed with resin will do the job








(gg) Q-cells will help to fix the cracks and fill-up the missing parts



(hh) When the shaped blank is shaped, the off-cuts represent about 30% of the blank weight before shaping.

 <p>(ii) The shaped blank is ready for decorating</p>	 <p>(jj) Here it will be the cranium in helmet</p>	 <p>(kk) Here it will be a little duck</p>
 <p>(a) Board is placed on the rack, and its bottom part is covered with a piece of cloth. The cloth is cut with about 2.5cm of excess on each end</p>	 <p>(b) Tail and nose sections are V-notched for avoiding the cloth to buckle when lapping it underneath</p>	 <p>(c) Catalysed resin is poured on the centre of the board and the cloth is fully wetted d.</p>
 <p>(d) Squeegee is used to spread the resin over the cloth until it is fully wet and then overhanging cloth is lapped underneath and excess resin is removed</p>	 <p>(e) Laminating resin stays tacky and is unsandable so sur-form is used to smoothen the rough surfaces</p>	 <p>(f) For deck laminating in some cases we used 2 cloths. Here the top layer was 135gsm cloth, and the bottom layer was 190gsm cloth in order to increase the strength</p>

Figure 2 Photographs showing the production sequences and tools used in hand laminating procedure of various surfboards. Photo courtesy: Audy J. – lecturer.

 <p>(b) Cloth was cut with about 2.5cm of excess on each end and the tail and nose sections were V-notched.</p>	 <p>(g) Procedure for deck laminating was similar to that described in (c) and (d)</p>	 <p>(h) Overhanging wet cloth was lapped with squeegee underneath</p>
 <p>(i) Sur-form was used to smoothen the rough surfaces</p>	 <p>(k) Masking tape was applied to the rails and the bottom part was covered with catalysed filler resin</p>	<p>After about 10 minutes (before resin fully cured) the masking tape was removed. The board was let to fully dry and the procedure was repeated on another side of the board.</p>

 <p>(l) Catalysed filler resin <i>ie</i> sanding resin was applying on deck, left, and bottom part , right, of the surfboards</p>	 <p>(m) The board was inspected</p>	 <p>(n) The resin was sanded using a sanding machine</p>
 <p>(o) or manually</p>	 <p>(p) The board was inspected</p>	 <p>(r) Hole for rope plug was drilled</p>
 <p>(s) Q-cells were mixed with catalysed resin and the rope plug was fixed in the hole</p>	 <p>(t) Fins were positioned on the board</p>	 <p>(u) Cloth strips were cut, catalysed resin was prepared and fins were laminated to the board. Masking tape was used to protect the surfboards from resin excess.</p>
 <p>(v) Fins were covered with sanding resin</p>	 <p>(w) After drying the fins were sanded</p>	 <p>(x) Situating plugs for removable fins</p>
 <p>(y) Drilling holes for the plugs for removable fins</p>	 <p>(z) Plugs were fixed in their holes using a mixture of Q-cells, short fibreglass strips and laminating resin</p>	 <p>(q) The excess resin was removed and the surface smoothed.</p>
 <p>(aa) The fins were fitted into the plugs to check their final position</p>	 <p>(bb) Hard resin edges were made on some surfboards</p>	<p>Then the whole surface of the surfboards was wet sanded by hand firstly using 400 grid and then 600 grid silicon carbide sand paper.</p>

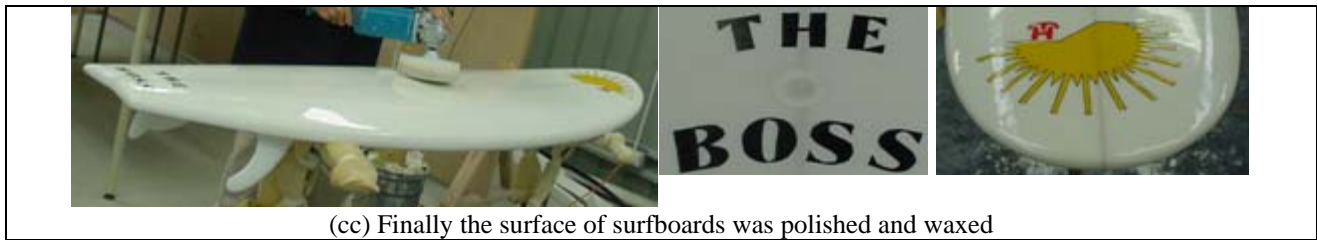


Figure 2 Continued from previous page

Each surfboard was designed in that way that it should provide a certain level of buoyancy for the surfer. Consequently, the board volume was closely related to the weight of a surfer. Moreover the surfing style, height of a surfer and his or her preferences for a certain type of waves were other factors considered in surfboard making activity. Students selected the moulded blanks that had their design features similar to that of the final surfboards. The length, width and thickness of the moulded blank were chosen according to the height and weight of the surfer. Further design features, namely, the rocker, rails, bottom contours, nose shape, tails, and fins were chosen according to riding style and wave preferences of the surfer.



Figure 3 Surfboards were born – we did it! Photo courtesy: Audy J., lecturer

3. Results

Figure 4 depicts some of the SST students with their surfboards designed and produced in the second semester of 2005.



Figure 4 Some surfboards designed and produced at ECU in the Second Semester of 2004. Photo courtesy: Audy J., lecturer.

From Figure 4 it is evident that a number of different surfboards were produced by the ECU students. The most popular appeared to be the thruster *ie* three fin design, only one of those students produced a two

fin design. Majority of these surfboards bore features similar to both a Type “Short”, 4’0” to 6’3”, and a Type “Fish”, 4’0” to 6’3”, surfboards. One student designed a Type “Mini Gun” surfboard with the length of 6’6”. Majority of students (~75%) got the templates from friends or shapers, other students (~10%) made templates for their surfboards by magnifying design features from ‘as published’ surfboard designs in various magazines, some students (~10%) copied the surfboard from an existing surfboard, and few students (~5%) calculated their surfboards for buoyancy. Students experimented with complex rail designs. Combinations varied from hard rails on tail for faster and less surface tension and soft rails from middle to nose for better manoeuvrability to high rails at nose, mid rails along middle and low rails along tail. The preferred tail shapes produced were swallowtail, pintail, round tail and squash tail. Moreover, the students showed a high level of art skill which is evident from the appearance of their surfboards. Therefore aesthetically nice looking surfboards seem to be of some interest. Finally, production took place between weeks 4 and 13 with most starting in weeks 5 or 6 thus the longest time taken for construction was about 9 weeks

In order to find out which criteria were important for our students when buying or making a surfboard, the students involved in surf-making activity were surveyed. The most important results are tabulated in Table 1. The results from this table indicated that mostly young people were interested in studying surf science and technology. Differences (\pm) in the height and weight indicated that the surfboards produced or purchased by those individuals would vary in length, width and thickness depending on the level of buoyancy needed by the surfer. Surfing activity was strong with 10 peoples surfing twice or more a week. It is expected that they must have also some surfing skill, and experience which would be useful for judging surfboard performance from an empirical point of view. When surveyed about surfboard ownership the average number of surfboards owned so far was 4 with the range of 9. The survey further indicated that the majority of students spent around \$600 per surfboard. This indicated that the students opted to have more surfboards for less cost, and would change their surfboard when damaged or old.

Table 1 The tabulated results associated with the survey conducted between the Surf Science and Technology Students at ECU in 2004.

PARTICIPANTS PERSONAL DETAILS	
Male	7
Female	8
Under 20 years old	9
Between 20 and 25 years old	4
Over 20 years old	2
Average height of males [cm]	175 \pm 5.5
Average weight of males [kg]	75 \pm 12.5
Average height of females [cm]	163 \pm 9.5
Average weight of females [kg]	57 \pm 8

SURF-BOARD(S) OWNERSHIP	
Do not have a surfboard	0
Own 1 surfboard	6
Have more than one and less than 3 surfboards	4
Own more than 3 surfboards	2
Average number of surfboards owned so far	4 min 1 max 10 (range 9)
Do not remember how many surfboards owned	2

SURFING ACTIVITY	
Never been surfing	0
Surfing once a week	4
Surfing twice a week	4
Surfing more than twice a week	6

COST OF THE SURF-BOARD PURCHASE	
around \$600	12
between \$600 and \$1000	3
more than \$1000	0

CHANGING THE SURF-BOARD	
every six months	1
once a year	1
when its old or damaged	13

MOST IMPORTANT CRITERIA WHEN BUYING A SURF-BOARD	
the craft weight	8
the craft cost	13
the craft design/shape	14
the fin design	6
the number of fins	5
the craft durability	3
the craft appearance	2
the shaper	1
the surfboard / fin material	1

The last part of this survey was focussed on the ‘most important’ criteria when purchasing a surf-board. These criteria were: craft cost, craft weight, craft shape, fin design, number of fins, craft durability, craft appearance, craft sharper, and fin/craft material. The results were statistically analysed in order to conduct a quantitative comparison of relative importance of various qualitative criteria with respect to each other. The results are presented and discussed from both qualitative and quantitative point of view in the following section

Statistical significance of each criterion against others was determined from the percentage difference

between the two criteria that was calculated using Equation 1.

$$\begin{aligned} \% \text{ difference} &= \frac{100.(Criterion1 - Criterion2,3,4,...9)}{Criterion1} \\ \% \text{ difference} &= \frac{100.(Criterion2 - Criterion1,3,4,...9)}{Criterion2} \end{aligned} \quad (1)$$

$$\text{eg } \% \text{ difference} = \frac{100.(CraftCost - CraftWeight)}{CraftCost} = \frac{100.(13 - 8)}{13} = 38.5$$

Whenever the percentage difference between two mutually compared variables was less than plus and/or minus 25% both criteria were considered to have the same level of statistical significance which was marked as 1. For percentage differences higher than positive 25% the first variable was more significant than the second variable. In such cases the statistical significance numbers were 2 and 0 for the first and second criterion, respectively. When percentage differences were more negative than negative 25% then the first variable was less significant than the second variable. In such cases the statistical significance numbers were 0 and 2 for the first and second criterion, respectively. An example of determining statistical significance of the craft cost criterion against the other eight criteria, namely craft weight, craft shape, fin design craft/fin material, is shown in the following Table 2.

Table 2 A key to determine statistical significance of one criterion against other criteria

Craft Cost versus	Craft Weight	Craft Shape	Fin Design	Number of Fins	Craft Durability	Craft Appearance	Craft Sharper	Craft/Fin Material
13	8	14	6	5	3	2	1	1
% difference	38	-8	54	62	77	85	92	92
Significance of Craft Cost versus	2	1	2	2	2	2	2	2

The same approach was used to calculate the percentage difference(s) and statistical significance coefficient(s) for all possible criterion to criterion combinations. The qualitative criteria and their corresponding significance coefficients are tabulated in Tables 3.

Table 3 Statistical results showing the perceived relative importance, q_i , for variety of qualitative criteria, calculated from responses of the 2nd year students involved in surf-making activity.

	Craft Weight	Craft Cost	Craft Shape	Craft Durability	Craft Appearance	Craft Sharper	Fin Design	Number of Fins	Craft/Fin Material	D_i	q_i
Craft Weight	---	0	0	2	2	2	1	2	2	11	0.152
Craft Cost	2	---	1	2	2	2	2	2	2	15	0.208
Craft Shape	2	1	---	2	2	2	2	2	2	15	0.208
Craft Durability	0	0	0	---	2	2	0	0	2	6	0.083
Craft Appearance	0	0	0	0	---	2	0	0	2	4	0.055
Craft Sharper	0	0	0	0	0	---	0	0	1	1	0.014
Fin Design	1	0	0	2	2	2	---	1	2	10	0.138
Number of Fins	0	0	0	2	2	2	1	---	2	9	0.125
Craft/Fin Material	0	0	0	0	0	1	0	0	---	1	0.014
										D_i	q_i
										72	0.997

For each criterion (1 ... i ... 9), in Table 3 the relative quantitative importance (q_i) was calculated using Equation 2.

$$q_i = \frac{D_i}{\sum D_i} = \frac{D_i}{D} \quad (2)$$

In Equation 2, the D_i represents the individual quantitative pointer for each qualitative criterion, and was calculated as a sum of statistical significance numbers in a row *e.g.* for craft weight criterion had $D_i=11$ *i.e.* (0+0+2+2+2+1+2+2). The D represents the statistical sum quantitative pointer of all D_i values for the whole sample set. The sum of relative quantitative importance (q_i) values should be equal to 1 for overriding importance/significance.

To determine the quantitative importance of each qualitative criterion in the sample group the qualitative criteria were rearranged in order from highest to lowest relative quantitative importance according to their q_i values, see Figure 5.

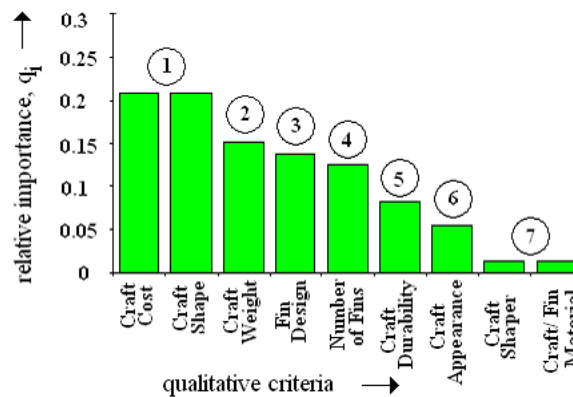


Figure 5 Histogram showing a relationship between the relative importance values and qualitative criteria with reference to data in Table 3.

4. Discussion

From Figure 5 it is evident that for this group of students the most important factors were the craft cost and craft shape (both with $q_i=0.208$). Other important factors were craft weight ($q_i=0.152$), fin design ($q_i=0.138$), and number of fins ($q_i=0.125$). Less important factors were craft durability ($q_i=0.083$) and craft appearance ($q_i=0.055$). Surprisingly the criteria associated with the craft shapers and craft fin material had very low importance factor (*ie* $q_i=0.014$). From this analysis one can deduce the following: The economical importance of purchasing the surfboards became more evident when 80% of respondents indicated that they are willing to spend around \$600 or less for the surfboard(s), and that 87% of them would change their surfboard(s) only when old or damaged, see data in Table 1. This shows that all improvements in surfboard construction that are currently sought through the changes in design and materials should not exceed the \$600 level for the surfboards to be sold, and hence be able to compete, successfully in open market. Craft shape was appreciated as functional variable that influence the performance of the surfboards. The craft weight was supported by 53% of respondents. The current trend in surfboard production is to reduce the craft weight as much as possible. However, this feature is not isolated from others. It affects mechanical properties of surfboards, so when surfing, strange things can happen. Boards break where they should not, mostly because of their inability to deal with wave impact forces due to reduced strength, stiffness and toughness. Generally, reductions in the weight are sought via reductions in surfboard thickness features. This approach however reduces both strength and durability. There are some possibilities to reduce the craft weight by reducing the number of fibreglass layers, and squeezing resin off the cloth when embalming the foam core, but the penalty is reduction in stiffness. Stiffness can be improved by replacing the common E-fibre glass with carbon fibres but the penalty is increased cost. It is therefore evident that the choice of correct material(s) is critical and requires a full understanding of all the interactive factors. It is recognized from experience that the qualitative level of the whole surfboard is ultimately dependent upon the level of the weakest – most inadequate – part of the total product which can be any variable in material and design features. To maximize quality the whole quantities have to be lifted to a similar level. This level, however, has to be economically sound. In contrast, the recent survey has shown that our students have a tendency to underestimate the role of materials in surf board production since the craft/fin material criterion was ranked at the tail of group order similarly as craft shaper. The fact that the craft shaper criterion had very low impact factor ($q_i=0.014$) indicates that it does not matter who shapes the board unless the craft has the right shape and appearance. Finally the survey results showed that the number of fins was a highly sought

surfboard feature ($q_i=0.125$), supported by 34% of respondents. These respondents probably prefer the three fin design (known as thruster) invented by Simon Anderson in early 1980's. According to our statistical results the number of fins was almost as important as the fin design see group order numbers 5 ($q_i=0.125$) and 4 ($q_i=0.138$), in Figure 5. However, the increases in fin numbers would result in increases of the craft weight, unless other improvements are done via fin design and fin materials. Thus, it is apparent that a surfboard that has to be treated as a complex system with mutual interrelationship between its various qualitative and quantitative measures. Consequently, there is a need to gain a deeper understanding of potential of various manufacturing procedures and materials may have on improvement of design and performance of surfboards.

5. Conclusions

Conclusions that can be drawn from this study are summarised as follows:

The authors were granted a "Teaching and Learning" grant which was used to support the surfboard making activities.

The students responded well and enthusiastically to the laboratory work because:

1. they were able to design their own surfboard that would suit best to their surfing style and ability.
2. they learned about shaping and laminating procedures relevant to those used in real industrial production.
3. they were able to use their results from other SST units lectured by the same lecturer to improve the design of their surfboard.

Type Short (three fin – thrusters) were the most produced surfboards. One student made a type two fin short board. One student made a type 'mini' gun surfboard. All the surfboards had complex rail design. Hard rails were preferred on tail and soft rails from middle to nose. Few boards were designed to have high rails at nose, mid rails along the middle and low rails at tail. Type swallowtail appeared to be the most preferred tail shape. The manufacturing cost was ~\$200 which was substantially less than ~\$600 for average priced commercial surfboards. The shortest and the longest time taken for the surfboard construction were 2 weeks and 9 weeks respectively.

It was recognized that for purchasing or designing a surfboard it is necessary to consider the following criteria: craft weight, craft cost, craft design/shape, fin design, number of fins, craft durability, craft appearance, sharper, surfboard / fin materials. These criteria were found to be mutually linked to each other and cannot be treated separately if the surfboard is to be evaluated as a whole system. Our study showed that a variety of literature sources refer to above criteria in rather descriptive and qualitative way, and provide very limited or no quantities for quantitative comparison. Consequently the SST students - those involved in surfboard production - were surveyed and the results were statistically analysed. This approach helped to finalise on scientific base a final order in importance of criteria that were used by our SST students for purchasing or building a 'best-fit' surfboard. This order, from best to worst, was: Craft Shape and Craft Cost, 1 ($q_i=0.208$), Craft Weight, 2 ($q_i=0.152$), Fin Design, 3 ($q_i=0.138$), Number of Fins, 4 ($q_i=0.125$), Craft Durability, 5 ($q_i=0.083$), Craft Appearance, 6 ($q_i=0.055$), and Craft Shaper and Craft/Fin Material, 7 ($q_i=0.014$). This indicated some underestimation of effects of materials ($q_i=0.014$) against other, higher ranked criteria. Consequently, more work is needed to study potential of various manufacturing procedures, materials and design features that may improve the performance of surfboards.

6. Acknowledgement

The author would also like to thank the ECU for providing the "Teaching and Learning" grant which allowed the purchase of materials for surfboard making activity.

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