# SUSTAINABLE DEVELOPMENT PRIMERS FOR DESIGN STUDENTS: A COMPARATIVE STUDY

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**ABSTRACT**
Within the higher education sector there has been progress incorporating or embedding sustainable development concepts into the engineering and design curriculum. Despite guidance from the Engineering Council and other institutions highlighting the wider qualitative aspects these are largely ignored within engineering and design education in favour of the more quantitative environmental and economic impact methodologies. To promote student understanding and engagement with the concepts of sustainable development an introductory primer was developed utilising both PBL and PAL methods. The course was delivered to mixed groups of first and second year BSc Design Engineering students during the first week of 3 consecutive academic years. The first course examined a product of clear social usefulness and the barriers to consumer acceptance in unfamiliar markets. The second utilised design analysis for technical understanding before students differentiated between product types through functional service, social value and material utilisation. The third included students drawn from BA Design Business Management. The foci were up-stream resource supply elements that threaten enterprise resilience rather than the customer perspective. The outputs identified a clear transition of understanding amongst the students for each of the primer courses. However, the most successful were those that held the design process and physical artefact at its heart.

*Keywords: Sustainable, design, engineering, resources*

## 1 INTRODUCTION

Sustainable Development is typically described from the Bruntland report [1] as: *"development that meets the needs of the present without compromising the ability of future generations to meet their own needs."* This definition focuses upon needs and resources but is often modified or taken out of context. However, the same report has a more distinctive definition: *"In essence, sustainable development is a process of change in which the exploitation of resources, the direction of investments, the orientation of technological development; and institutional change are all in harmony and enhance both current and future potential to meet human needs and aspirations."*

Here the focus is upon the interdependent nature sustainability; how resources, enterprise, technology, government and people interlock to meet needs and aspirations. Although there are a wide range of definitions and models, often contradictory in nature, the principles remain [2]. Sustainable Development is often represented through the three pillars (Figure 1) first described by Barbier [3];

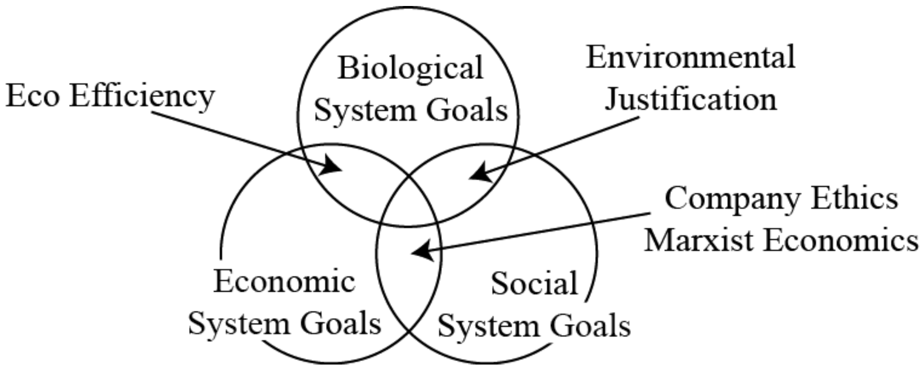


*Figure 1. Sustainable Economic Development Goals [3] and Interface [4]*

definition for the interface between spheres varies with Hauschild describing them as eco-efficiency, company ethics and environmental justification [4] while Barbier represented that between the Social and Economic as Marxist Economics.

### 1.1 Educational challenges of Sustainable Development in design and engineering

The very nature of Sustainable Development is often viewed as too complex or diverse to be successfully integrated within Higher Education [5]. Where it has been introduced, it has been directed toward the environmental and economic, the domain of eco-design or eco-efficiency, largely ignoring the social [6-7].The reluctance to engage with the social sphere can be related to the nature of the methodologies involved; the familiarity of quantitative methods reflects toolsets such as life cycle analysis (LCA) and cost benefit analysis (CBA) within the environmental and economic [8]. Where the social sphere is addressed in the literature it is typically restricted to enterprise level impacts such as company ethics, rather than direct social impact of the product [9]. Institutional guidance from the Engineering Council UK [10] and the Royal Academy of Engineering [11] encompasses the social sphere and interlocking nature of sustainability. More recently, the concept of social usefulness has been developed as a tool to raise awareness and understanding of the social sphere of sustainability within both education and enterprise [8] and is directly linked to the product rather than the enterprise.

## 2 APPLICATION TO DESIGN ENGINEERING EDUCATION

A methodology for implementing the concept was developed from the ongoing research and international best practice; using a combination of problem based learning (PBL) and peer assisted learning (PAL) to explore sustainable development issues and relate them to engineering and design [8]. The methodology was deployed over a three year programme during the first week of the academic year during which no other units were taught (Primer A: 2009-10, Primer B: 10-11 & Primer C: 11-12). The context of Sustainable Development varied for each and was delivered to mixed groups of first and second year BSc Design Engineering students. Didactic elements were restricted or omitted with learning delivered through student investigation, discussion, presentation and reflection.

### 2.1 Primer Delivery

Each of the primers followed the methodology outlined above but examined the application of sustainable development concepts to design and engineering from alternative contexts by examining the barriers presented (Figure 2).

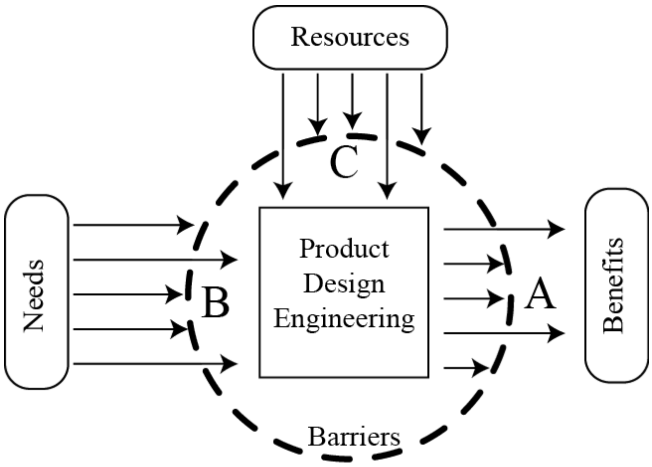


*Figure 2. Barriers to Sustainable development in Design & Engineering: Where A is cultural values and tradition; B is product perception; C is scale and viability*

Primer C examined up-stream elements that threaten enterprise resilience rather than the familiar customer use or manufacturing phases, barriers here are represented by scale and viability.

### 2.2 Primer A: Barriers to trade in unfamiliar markets.

The first primer [12] examined the barriers to acceptance of a product that has clear social usefulness through its benefits to the customer and wider society; here the barrier can be represented through cultural values, customs and tradition. The product selected was a mosquito net to be designed for production and marketing within the Niger Delta region of Nigeria. For this Primer, there was no didactic element; instead students presented their findings at regular briefings, the first after two hours. These initial presentations offered design solutions without examining the wider context of sustainable development, specifically market barriers. Discussions after each round of presentations involved all student teams with staff acting only as facilitators. Issues discussed included: how malaria is caught, local beliefs, barriers to use, approved materials, distribution, re-treating, disposal, encouraging correct use. Students began to appreciate the broader concepts of Sustainable Development and the importance of these qualitative, social aspects. During the final two days teams constructed prototypes, justified their design decisions and delivered their final presentation. Within their presentations students identified a reluctance to use mosquito nets, citing a long standing belief that malaria is not caught from the mosquito; instead malaria was attributed to spending too long in the sun or eating too much fatty food. Others identified the role of traditional healers and attributed severe malaria to evil spirits and hereditary factors. Students identified that for their product to be successful they had to overturn, or challenge, this existing cultural belief.

### *2.2.1 Assessment of effectiveness*

Primer effectiveness was measured by issuing identical questionnaires to students before and after the programme. The first question asked students to match stakeholders against seven issues with responsibility ranging from none (0) to high (3). Issues evaluated were: product cost, environmental impact, human cost, social impact, profit, disposal and packaging. Sustainability issues were segregated and combined to form a sustainability index and overall change in perceived responsibility. Results showed a change in student perception with increased recognition for the responsibility of the designer towards sustainability issues, although results were within a margin of error.

The second question asked students to rank a range of design criteria, both conventional and sustainability orientated, in order of importance. Here the change was more defined with conventional criteria such as aesthetics and ergonomics becoming less important than before and sustainability issues such as human cost, resource depletion and social usefulness ranked more important.

For the third question students rated their own understanding of sustainable development before being asked to define the context of sustainable development using 80 words, this evaluated both change in understanding and the level of over-perception. Both sets of students claimed greater understanding than they actually had and was the case both before and after the exercise. However, there was a significant change in understanding demonstrated by the subjective evaluation of their answers, especially amongst second years. More significantly, this understanding was also demonstrated in the final presentations and open discussions over the course of the week. During this process, students recognised the need to challenge existing cultural beliefs. On a global scale, the real challenge of sustainable development is to change accepted western cultural belief!

## 2.3 Primer B: Social Usefulness as a design tool.

The second primer [13] utilised design analysis for technical understanding before encouraging students to differentiate between similar product types through functional service, social value, product service mix and material utilization; barriers here can be represented by product perception.

Groups were each provided with a brand new boxed domestic product: electric citrus juicer, electric can opener, electric hand blender, kitchen scales, cordless screwdriver. Each group was given 2 hours to prepare and deliver a 5 minute oral presentation followed by feedback and open discussion. A micro-seminar discussing the design process preceded a new goal for the next day's presentation; students were asked to provide a technical analysis examining the materials, processes and technologies utilised in their products as well as quantifying the operational performance. The second round of presentations, feedback and discussion of salient points raised by the groups were followed by a micro-seminar on sustainability in design. This included topics such as social usefulness, resource depletion, product as a service delivery mechanism, scale and end of life; students were asked to examine their products from a sustainability perspective and deliver a third presentation the next day. Following presentation, feedback and discussion, students were asked to examine the functional design and materials palette to transform for an alternative market, from "value" range to a premium product. Within this 48hr period, groups were provided with consultations delivering guidance through questioning rather than direction. The final presentations brought all the discussed elements together with groups expected to justify their decisions from social, environmental and economic perspectives.

#### *2.3.1 Assessment of effectiveness*

Student understanding of both social usefulness and material utilisation were recorded from the third and fourth presentations, summarised and discussed.

For the citrus press, recognition that the product was a "gimmick" and associating "showing off" revealed the group distinguishing between aspirational and inspirational products. Examining the product's function from a wider perspective reveals there is little or no social usefulness to the product.

For the electric can opener, social usefulness was demonstrated for the physically impaired; however, as a low cost consumer product has little or no social usefulness.

In the case of the kitchen scales the group recognised the product was purchased to satisfy a need and that it could displace reliance upon ready meals. This is well founded since the product allows the user to take responsibility for what they eat, and feeding their family. It can be viewed as an inspirational product rather than aspirational.

For the rechargeable screwdriver, the students merely described a benefit that the function delivers. The product's poor performance yields little real social usefulness. The group did discuss improving performance and alternative routes to market but not within the context of social usefulness; such changes would yield a product that empowers the user and promotes self reliance.

For the electric hand mixer the social usefulness was derived from the wider context of the products function and well defined. However, while this would be the case for a product that delivered upon its promised performance, the actual performance fell short.

It was clear that products with a genuine social usefulness were relatively easy to identify and the social usefulness easy to define. Where products had little or no social usefulness, students struggled to recognise this and attempted to persist with weak definitions, even where they had acknowledged their products were "gimmicky", more suited to an alternative market or unable to deliver the level of performance required.

### 2.4 Primer C: Supply Chain Challenges.

Building upon the experience gained and the ongoing research a revised primer was developed and expanded with students also drawn from BA Design Business Management. The primer focused upon up-stream elements that threaten enterprise resilience rather than examining from the customer use phase; barriers here are represented by scale and viability. Groups were provided with a single word or title (rather than physical product, description or image) of an apparently sustainable technology: HAWT, EV, PV, Hydrogen Fuel Cell Vehicle, Tidal Energy, Bio Fuels, Biomass Boiler. Groups were given two hours to provide a 5 minute oral presentation describing the technology used. For the second round of presentations, conducted the following day, students were asked examine the viability and justification of the technology. They were directed to investigate the problem the technology is intended to solve and examine the viability from a materials supply chain perspective. The presentations were followed by a short seminar on sustainable development in design and engineering outlining concepts such as resource depletion, limits of extraction, social usefulness, efficient material utilization and substitution. For the third presentations, students were asked to consider a number of aspects: Scale, how many do we need, want, have? Quantity of materials required? What will it achieve? What has it changed? Alternative solutions for the problem we are trying to solve?

The Final presentations asked students to build upon the previous outcomes and reflect upon the feedback and open discussions to investigating the supply chain, hence identify weak links in the long term viability of the technology. Students were encouraged to examine the real purpose of the technology, what it is really used for, the viability of solution and how the technology fits within the concept of sustainable development. To assist in the final task each group was allocated 5 minutes of consultation with the supervisory team.

#### *2.4.1 Assessment of effectiveness*

Student understanding of viability, scale and fit within sustainable development were evaluated from their third and fourth presentations, as follows:

For EV's, students recognised the resource constraints of rare earth elements (REE's) to technology scaling, they questioned why the car is used and the technical limitations of the technology. The group also commented *"we will look back in hindsight and think...shouldn't we have done things differently?"* However, their grasp of social usefulness or social value was weak.

For tidal energy, students recognised purpose in the wider context of maintaining standard of living and the problem of expanding demand to meet wants rather than needs. However, while they discussed materials from an impact perspective they failed to recognise issues with supply of non-renewables and REE's.

For HAWT, students identified the need to adjust lifestyle and technology simultaneously, essentially tackling supply and demand together. They also noted that it was a blend of solutions that would lead to a best solution rather than any one. Although they examined the scale of deployment needed they failed to recognise supply constraints on materials used at this scale.

For PV's, the group examined the fit to sustainable development, recognising the viability from an environmental/economic impact perspective. They also identified the change to lifestyle that would be required to adjust the demand side. They noted that the performance was dependent upon location and should be deployed appropriately. However, they failed to examine the material resource constraints when the technology is developed to a global scale.

For biofuels, the group recognised the issue of scale when large land areas are used for production (food vs fuel) and the limited effect the technology can have. Students recognised that viability was dependent upon the location and scale. However, they struggled to describe the fit with sustainable development or identify the wider context of function.

For biomass boilers, the group discussed how the technology had a good fit with sustainable development, when applied appropriately. They recognised that other technologies could reduce demand hence resources required. They noted that viability was dependent upon the feedstock supply chain, hence location and scale. Although they examined the feedstock supply chain they failed to examine the materials resource constraints.

For hydrogen fuel cell vehicles, students examined the wider context, identifying the proliferation of the car, poor material utilisation and questioning if it is a need or a want and recognised the up-stream issue of supply for platinum. They also examined viability, identifying public transport systems as more suitable for the technology. However, they did not identify the source of the hydrogen fuel or other materials that may hinder the technology scaling up for a global market.

## 3 COMPARISON OF OUTCOMES

The three primers each examined different barriers to product development but can be bound through the concept of social usefulness. In the case of Primer A the student outcomes demonstrated development and understanding of wider global issues outside their normal community and culture. The students, however, did not develop methodologies for identifying social usefulness itself. Outcomes from Primer B showed that success in identification of social usefulness was largely dependent upon whether the product actually possessed social usefulness. Where social usefulness was positive it was clear and readily identified. However, when it was not students persisted in trying to identify something that did not exist. This was as much a reflection upon the student emotional attachment as the difficulty in identification. The outcomes from Primer C demonstrate that the cohort as a whole did manage to examine the wider issues and resource constraints that can restrict development at a global scale. They discriminated between technologies capable of meeting their potential, those suited to niche markets and those that could be considered unsustainable. However, individual groups found it difficult to link the technologies to sustainable development beyond their apparent headline promise, into the wider impact of the product type and supply chain resource constraints. Individual students struggled to challenge the credentials of the technologies, accepting them at face value.

Contrasting the outcomes it is clear that the inclusion of the practical design tasks provides focus for the students to engage fully with the project. In contrast, the up-stream resource orientated nature of Primer C did not contain any design tasks to engage with and may have been viewed as a side project, rather than a practical element of their academic programme. Students from both Primer A and B also identified that an overwhelming social benefit can over-ride the resource constraint or environmental impact. Both Sets of students from A and B subsequently used the methodologies described during project units, particularly from Primer B, this did not happen with students from Primer C. From a research perspective, the outcomes have led to the development of the social usefulness test [8, 12], material utilisation [13] and the barriers model (Figure 2).

## 4 CONCLUSIONS

Each of the primers allowed students to challenge their preconception of product viability, market scale and needs; taking students beyond the normal "eco-design" to meet the institutional guidelines. The programme has promoted an understanding of the impacts of decision making, outside of the designers traditional sphere of influence. As a result all students gained an understanding of the broader concepts of SD and impact on the wider community. Primer B, which was clearly the most successful, stands out from the others in 2 ways. Firstly, students gained knowledge about the product through hands on disassembly and technical analysis before being introduced to sustainable development. This provided students with intrinsic interest in the project and emotional investment in the product. Secondly, throughout the project, students were balancing the sustainable development issues against the design process, in which they have familiarity. While Primer A had some of these elements, the design process was not integrated into the programme as it was with Primer B. Primer C lacked this integration to the design process and students found difficulty in defining the problem being set or the goals of the project; this led directly to the issues identified above. The PBL/PAL method has proved successful in engaging first and second year design students with sustainable development. The most promising methodology involves integration with the design process itself, rather than in isolation or as a side issue. The programme also yields student development, encouraging self-directed learning and mentoring skills while first year students acquired basic design skills directly from their peers.

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