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Carbon Footprinting for Design Education

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Abstract: *The use of Carbon Footprinting as a metric for gauging the sustainability of products has gained momentum in the past five to ten years. As such it needs to be introduced to design students studying sustainable design modules, despite the recognised limitations of the approach. Following the completion of the literature review, a teaching package comprising an introductory lecture, the new carbon footprinting tool – 'Dirty Carbon' and a practical workshop were developed. The new tool was assessed with design students against an industry leader called 'Sustainable Minds'. Students (n=42) were provided with contextual information on what a carbon footprinting is by attending the lecture, then taught how to use the two tools and asked to perform a full carbon footprint analysis of a product using both tools within a workshop setting. The outputs from the project showed that Dirty Carbon outperformed the market leader in a teaching context. Further testing through end of semester exams demonstrated that the new teaching package had contributed to a high level of knowledge attainment regarding carbon footprinting.*

Keywords: *carbon footprinting; ecological indicators; design; higher education*

Introduction

Carbon footprinting is a "widely used metric of climate change impacts and the main focus of many sustainability policies among companies and authorities" (Laurent, Olsen, & Hauschild, 2012) it is a methodology which measures the environmental impact of a product, service, organisation or individual in tonnes of carbon dioxide equivalent (tCO_2e). However, environmental sustainability is concerned with issues beyond climate change, such as chemical pollution and the depletion of natural resources. The focus on carbon footprinting can lead to the risk of carbon being reduced at the expense of inadvertent increases in other environmental impacts (Laurent et al., 2012). These limitations and others have meant that in the past the teaching team in the Design School at Loughborough University have selected not to teach carbon footprinting to the undergraduate or postgraduate industrial/product design students. Instead the EcoIndicator 99 (Goedkoop, 1995), CES (University of Cambridge, 2008), Abridged Design Abacus (Bhamra & Lofthouse, 2007) and Social Issues cards (Lofthouse, 2013) have been taught.

- EcoIndicator 99 developed by Pre Consultants B.V. (www.pre.nl) is a life cycle analysis tool, that quantitatively assesses the impact of a product or system, using over 200 pre-defined 'eco-indicator values' for common materials and processes. It provides a quick assessment of a product or systems with respect to its impact on: damage to human health; damage to ecosystem quality and damage to resources in millipoints (mpts). It is a direct competitor to the Carbon footprinting approach and provides a much more comprehensive review of environmental impact
- CES EduPack© is a tool created by Granta Design Limited in Cambridge, predominantly for material sciences. The tool is split into a variety of database levels, which allow access to a variety of material types and associated manufacturing processes. It also allows levels of complexity (from introductory to advanced) to be chosen for a particular field of enquiry, such as ecodesign, architecture, bio engineering and aerospace. The tool also offers additional teaching and student resources within each database level.
- The Abridged Design Abacus is a qualitative tool which helps designers to assess the sustainability performance of a product, highlight the areas where further research is needed and outline the targets for their redesign. It can be used to analyse the performance of an existing product, to compare a number of alternative design solutions and to make detailed comparison against other designs. Using the 'Abacus' designers can evaluate a product against specific criteria, under a range of focal areas: lifecycle (manufacture, use, end of life, packaging); social (need, social enrichment); other (cost, quality, aesthetics).
- The Social Issues cards are a set of 31 handheld cards created to help designers consider relevant social issues in their design work. They combine a series of relevant questions and illustrative case studies to demonstrate how others have addressed the question posed. They can be used as a stand-alone tool by individuals or groups of designers and also be used in conjunction with tools such as the Design Abacus to encourage consideration of social issues alongside environmental issues.

In recent years carbon footprinting has increased in popularity as a tool to measure the sustainability of a product. It is now the most commonly used indicator of sustainability within product design, architecture and any company that wishes to highlight good corporate social responsibility (Cholette & Roeder, 2012; Humphries-smith, 2007). Figure 1 illustrates the level of interest that carbon footprinting has garnered within academic discourse and shows the amount of literature that is being dedicated to carbon footprinting over other ecological indicators. As such its role in sustainable design education needed to be reconsidered.

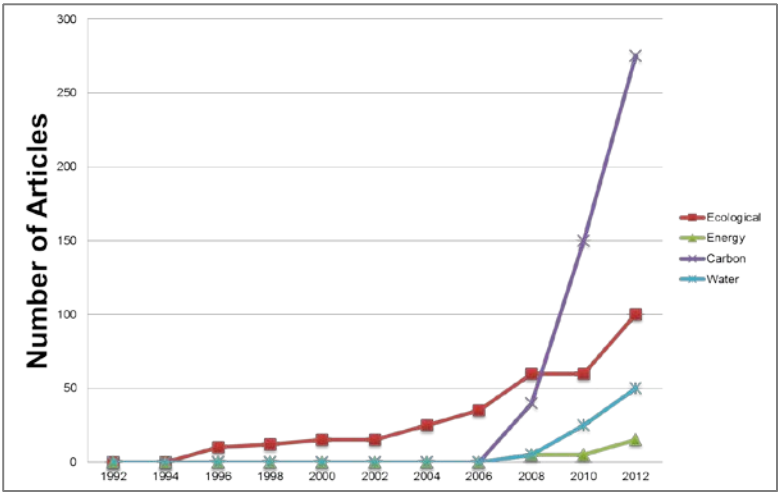


Figure 1: Popularity of Carbon Foot Printing in Academic Discourse (Adapted from Fang et al. 2013)

There are a number of reasons as to why carbon footprinting has become more popular than other ecological indicators. It is comparatively simple to use and available to calculate online (Weidema et al., 2008). It takes into account the non CO2 emissions and, as such, is more accountable (Fang, Heijungs, & de Snoo, 2014), and the calculated value is easily grasped and placed in context (Berners-Lee, 2010; Weidema et al., 2008).

The popularity of carbon footprinting as an ecological measure has coincided with the uptake of a range of corporate social responsibility initiatives within industry where the use of carbon footprinting, rather than other ecological indicators, has become an industry standard for justifying the sustainability of their products (Weber, 2012). In 2014, 85 FTSE 100 companies reported carbon data in their annual reports, (potentially as a 'result of mandatory greenhouse gas reporting regulations') (Chadwick, 2014). In parallel with this, the team at Loughborough University have found there has been an increased desire from companies who set live projects for students, to see a completed carbon footprint analysis as part of the project output. These developments led us to believe that there was a need to provide students with the skills to be able to carry out carbon footprint calculations (despite its flaws and limitations). It was recognised that providing this knowledge would better prepare them for a role in industry, where carbon footprinting is an industry standard.

Currently most if not all carbon footprinting tools are developed for industry. These requirements are not necessarily in line with the needs of student designers, who don't need to become experts in the area. Undergraduate design students are likely to only use the tool sporadically and will not have access to much of the industrially oriented data (material sources, sales figures, embedded water) often required by these tools. Additionally, when being introduced to a new complicated subject, the necessity for simple, understandable language is important for student engagement. This is often not the case in existing carbon footprinting tools. Finally, current tools tend to require a reasonable financial investment, which has limitations for some institutions and for students who are on placement in small to medium enterprises and want to demonstrate knowledge in this area.

In recognition of these issues an opportunity was sought through an internal Teaching Innovation Award to run a practice-based, pedagogical project to develop an appropriate carbon footprinting tool for design students. It was carried out in collaboration with a local environmental consultancy Ape who had an outline carbon footprinting tool that they were happy for us to develop further - a beta version of a Microsoft Excel database, created using data from open source databases from the Office of National Statistics and Small World Consulting Ltd. This paper reports on the creation of a more refined tool, 'Dirty Carbon' (and supporting material) and its subsequent evaluation against a market leader 'Sustainable Minds' (Sustainable Minds, 2015) with design students at Loughborough University.

Literature review

A literature review was carried out to enhance subject knowledge, identify current and effective practice in the teaching of carbon footprinting to design students and to identify case study examples to help make carbon footprinting relevant and interesting to the students. A number of the key relevant findings are presented here, specifically an introduction to the key attributes and limitations of carbon footprinting, literature relating to best practice in teaching carbon footprinting and literature concerning the development of tools for designers.

Attributes and limitations of carbon footprinting

A number of limitations of carbon footprinting have been alluded to in the early sections of this paper. These will be reflected upon more fully here as they are an important component in understanding the context of the subject.

Firstly, a key message from the literature, is that the boundaries that define what is included in a carbon footprint are often subjective and selective inclusion of stages of the product lifecycle alters the results that come from calculating a carbon footprint, making them variable and open to interpretation (Fang et al., 2014; Padgett, Steinemann, Clarke, & Vandenbergh, 2008; Ren & Su, 2013). The scope for a carbon footprint calculation can be as wide or as narrow as desired, including or excluding 'make', 'use' or 'dispose' phases. Any combination of these three phases can be put into a carbon footprint calculation, which makes comparisons difficult, as disclosure as to what has been included is hard to establish on a product-to-product basis (Shayler, 2014; Berners-Lee, 2010).

Secondly, it is important to recognise that CO2e values are at best an estimate. Berners-Lee (2010) explains that if a burger is estimated to have a carbon footprint of 2.5kg CO2e this probably means that it is somewhere between 1.5 and 4kg CO2e. This is echoed by Weber (2012) who states that carbon footprinting calculations can vary by ± 35%

depending on system boundary rules, aggregation error, temporal and geographic variability and technological specificity. Despite this, carbon footprinting is still a valuable method for identifying key areas to focus on, for example, reducing long haul flights (at approximately 3.4 tonnes CO_2e each) rather than focusing on how staff dry their hands (10g CO_2e per paper towel) (Berners-Lee, 2010). Overall it is seen that carbon footprinting is popular, but flawed and as Finkbeiner states "CFP is too bad to love it, but too good to leave it."(2009)

Thirdly, carbon footprinting has other more holistic limitations. Focusing on the carbon foot print of a product/service/system can distract attention away from more effective sustainable design strategies. As previously mentioned environmental sustainability is concerned with issues beyond climate change (Laurent et al., 2012). It can also lead to the social implications (the third pillar of sustainable design) being ignored (Elkington, 1997). Finally it is worth reflecting that carbon footprinting cannot be used for design concepts or to analyse products which do not have a predecessor. These are both common activities for design students.

Best practice in carbon footprinting teaching

During the literature review very little evidence of best practice regarding the teaching of carbon footprinting specifically to product and industrial designers could be found. A great deal of reflection regarding its teaching within the fields of architecture, chemistry, business and material sciences was available, which was interesting but did not lead to great insights for design. Through observing carbon footprinting in architecture and material sciences one can see that the assessment of raw materials is a key focus, which design students do not necessarily require (Aurandt & Butler, 2011; Ren & Su, 2013). The use of carbon footprinting within architecture is also more easily applicable with the calculations being made for a finite amount of materials, such as a building. Within product or industrial design, the calculations are needed for an indefinite or speculative product run, where quantities are often unknown. Within business courses, the introduction of sustainability modules is focused on understanding a system level approach, which includes processes without a focus on specific products (Cholette & Roeder, 2012).

The literature highlighted various tools commonly used in engineering education; Sustainable Minds (Sustainable Minds, 2015), CES EduPack (University of Cambridge, 2008), Solidworks plug in (Dassault Systems, 2014), Sima Pro (SimaPro UK, 2015) and Gabi (PE-international, 2104) (Ren & Su, 2013), which were confirmed by interviews with colleagues at a variety of design institutes around the world (in another section of the study). Ren and Su (2013) provide a subjective analysis of these softwares (see figure 2). Within this analysis the popularity of the SimaPro and Gabi tools are indicative of the fact they are being assessed against the needs of engineering students who require much more technical and life-cycle-analysis based results and analysis.

Considerations	CES	Solidworks	Sustainable Minds	SimaPro	Gabi
Product definition based on LCA	★★	★	★★	★★★	★★★★
LCIA Method	★	★★★	★★	★★★★	★★★
Database	★★★	★★★	★★	★★★★	★★★
Database Modification	★	★	★	★★★★	★★★
Presentation	★★	★★	★★★	★★★★	★★
Details	★	★★	★★	★★★★	★★★★

Figure 2: Carbon Footprinting tool analysis (taken from Ren, Su; 2013)

As a result the considerations that were assessed take into consideration the technical aspects of the tools, but do not reflect the needs of design students. The body of literature reviewed does not provide a thorough explanation of these footprinting tools in the context of product/industrial design education. This project set out to address this challenge.

Developing tools for designers

In light of this lack of best practice guidance it was necessary to draw on knowledge regarding designing tools for designers. The holistic framework in Figure 3 is described as a "design brief for Industrial Design focused ecodesign tools" (Lofthouse, 2006) and as such was considered as highly relevant for consideration within this project.

Figure 3: A holistic framework for Industrial Design focused ecodesign tools (Lofthouse, 2006)

The framework recognises that Industrial Design is a unique and complex discipline with a distinctive approach to problem solving, learning styles and working practices (Cooper & Press, 1995; Cross, 1994; Durling, Cross, & Johnson, 1996) that sets it apart from both art and engineering and as such, tools for industrial designers must be developed with this in mind, if cognitive dissonance is to be minimised (Lofthouse, 2006).

Through the framework seven elements: guidance, information, inspiration, education, visual, non-scientific language, and dynamic access are presented, though "its strength lies in the combination of the different elements" (Lofthouse, 2006). The framework represents the importance of providing a combined service of (simple and focused) guidance, ecodesign education and design focused information. This interaction ensures that designers can identify the important issues to address in ecodesign, find associated cases to illustrate how others have met these needs, and then back this up with focused, specific relevant information. The framework also recognises the importance of a combined content, which pulls together inspiration (via cases), with information (both traditional ecodesign data and more detailed design focused information) to ensure that good examples are linked to detailed information, which transforms them into really useful sources of data (Lofthouse, 2006). It also recognises that information needs to be appropriate to Industrial Design (i.e. address relevant issues) and provided in a language that designers understand, utilising images and minimal text (Lofthouse, 2006). The aim within this project was to develop a package of material which took into consideration as many of the attributes of the holistic framework as possible in the development of a carbon footprinting tool for designers.

Methodology

Following the completion of the literature review, an introductory lecture, the new carbon footprinting tool – 'Dirty Carbon' and a practical workshop were developed. Table 1 provides a summary of the way in which the attributes of the holistic framework were integrated into the package of teaching material. Following this, the content and format of the lecture, tool and workshop are described. The section concludes with a description of how the data, which enabled a comparison between Dirty Carbon and a market leader, was collected and analysed.

Table 1 Summary of the way in which the attributes of the holistic framework were integrated into the package of teaching material

Elements of the framework	**How these were addressed through the package of material**
Guidance	• Guidance regarding how to interpret carbon footprints was provided through the lecture • Guidance as to how to carry out a carbon footprint was provided in the workshop via a video/PowerPoint presentation incorporating a walkthrough of the tools
Information	• Detailed examples provided through the industrial case studies provided by Ape • Care was taken to ensure that the areas addressed within Dirty Carbon were relevant to industrial designers • Product related information was provided in the Data Sheet
Inspiration	• Inspirational detailed case studies which are relevant to designers, were provided through the lecture
Education	• The whole package (lecture, tool and workshop) was educational
Dynamic access	• Dirty Carbon was provided on the intranet so that it could be accessed for this and future projects • Dirty Carbon was available for free for students to download

Non scientific language	• This was avoided • Text was kept to a minimum within the tool
Visual	• This was a major consideration in the development of Dirty Carbon, though there were considerable limitations as a result of the Excel software which formed the platform to the tool. • Visually interesting case studies were used in the lecture material • How to visually represent carbon data was introduced in the lecture drawing on leading work within industry.

INTRODUCTORY LECTURE

The key aims of the lecture were to introduce the concept of carbon footprinting, to set it in context, to highlight its limitations, to provide interesting case studies to engage the students and to demonstrate its relevance to them and their future employers. When it came to setting the context for carbon footprinting, the material drew heavily on the work of Berners-Lee (2010), which was excellent at bringing carbon footprinting statistics to life and made them interesting and relevant to a design audience (see Figure 4).

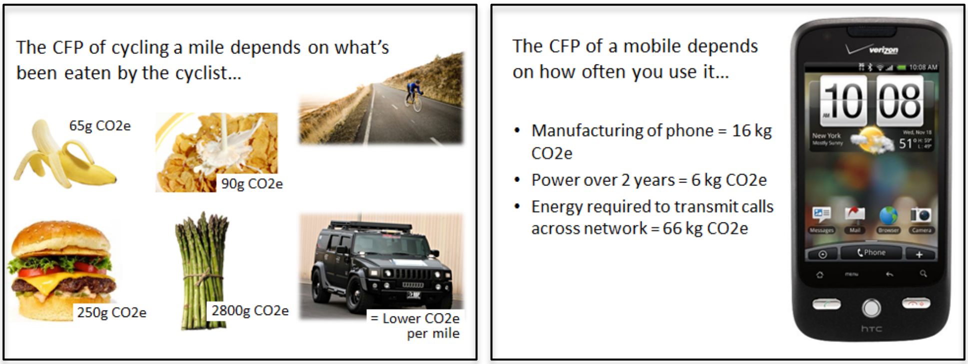


Figure 4 Screenshot of sample PowerPoint slides from the lecture material

Case studies were drawn from the literature from companies such as Apple (Apple Computer Inc., 2015) and Unilever (2014) who provide carbon footprinting information across their product ranges. Additionally, the collaboration with Ape meant that rich and detailed case studies from their consultancy work with Howies, Hiut Denim and Mu could be used (see Figure 5), which added considerably to the student experience. The involvement of an 'active' industry partner is recognised as an important ingredient in garnering student engagement with a subject (Lockrey & Bissett Johnson, 2013).

Figure 5 Excerpts from the Hiut Denim case study incorporated in the background lecture

Dirty carbon

The Dirty Carbon prototype tool (Figure 6) was developed in collaboration with Ape, who provided a beta version of the tool as an Excel database. The ability to build on an existing database was invaluable for this small, low budget development project. The tool was developed through a series of discussions, with students, staff and the collaborator, which took into account the needs of design students who would be approaching the subject of carbon footprinting for the first time. The characteristics of the tool, which were deemed important, were aggregated from the literature on carbon footprinting tools and from comparisons previously been drawn from academic assessments (Ren & Su, 2013; Lofthouse, 2006). The tool was trialled with academic staff and researchers throughout the development phase and developed iteratively.

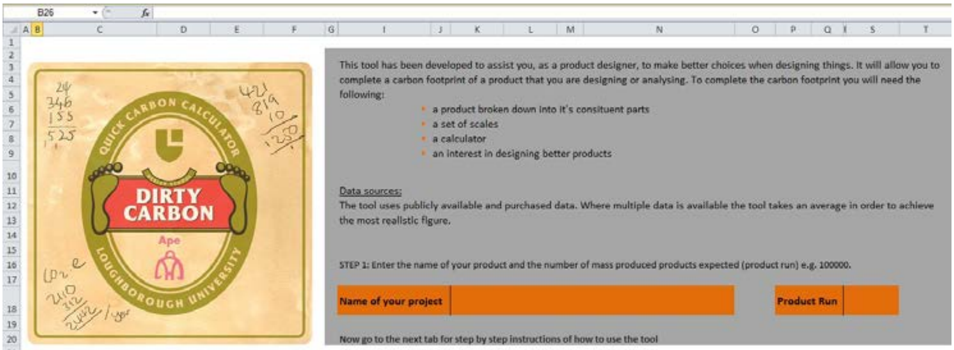


Figure 6 Screenshot of the Dirty Carbon tool homepage

A number of specific changes were made to the initial tool to make it more appropriate to the needs of entry-level design students:

- Introduction and guidance sheets were simplified.
- Pages relating to sales figures, embedded water calculations and other irrelevant considerations were removed.

- The amount of components that could be added for one product was increased to 15 to allow a product to be analysed in more detail.
- A final summary page for CO2e was added at the end of the tool – this allowed comparisons between a range of product and packaging options and provide all the relevant information on one page.

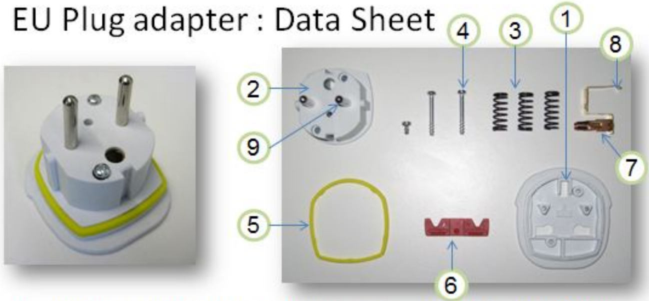
A requirement of the project was to compare the new tool to a market leader to establish whether this 'rough and ready tool' was detailed enough to provide a useful output, whilst meeting the simplified needs of the students. Sustainable Minds (Sustainable Minds, 2015) was chosen from the variety of software tools available due to: its accessibility online; the availability of a free trial period (15 days); the inclusion of visual outputs which could be used for comparison with the Dirty Carbon tool; its focus on a carbon footprinting calculation for products and because it required little training prior to the workshop for the students to understand how the tool worked.

A workshop in which Dirty Carbon and the Sustainable Minds tool could be compared was developed and run as a pilot with a small group of Masters students (where quick, aural feedback could easily be obtained, and any issues be quickly resolved), then as a main workshop with a group of 42 Industrial/Product design students enrolled on the second year elective Sustainable Design module.

The students were introduced to the subject of carbon footprinting through the introductory lecture (outlined above) with a gap of two days before the workshop, to allow them to absorb the information and read around the subject. At the start of the 2 hour workshop the students were given a Data Sheet for an EU converter plug (see Figure 7) which was developed to be the focus of the carbon footprinting analysis for both tools. The simple product, with its short parts list meant the calculations that the students had to make using two CFP tools, would not be too lengthy. The Data Sheet included images of the product before and after disassembly, a list of components (materials and weight) and two scenarios based on the distance the product was transported after manufacture, energy used in manufacture, length of life of the product and the proposed end of life solution. This helped to keep assumptions to a minimum and to expedite the process.

Carbon Footprinting for Industrial designers

EU Plug adapter : Data Sheet



This sheet provides you with the information needed to conduct a carbon footprint of the EU plug adaptor using the tools that you have been given.

Component Name and Number	Material	Process	Component Weight (kg)	Weight of 100000 units (kg)
Casing BIG (1)	ABS	Moulded	0.0085	850
Casing SMALL (2)	ABS	Moulded	0.016	1600
Springs (3)	Steel LOW CARBON	Formed	0.002	200
Screws (4)	Steel LOW CARBON	Formed	0.002	200
Band YELLOW (5)	ABS	Moulded	0.0005	50
Safety Bar (6)	ABS	Moulded	0.001	100
Connection Points (7)	Copper	Formed	0.001	100
Pins (8)	Steel LOW ALLOY	Formed	0.001	100
Fixings (9)	Brass	Processed	0.002	200
Bubble Pack (P1)	Polystyrene	Formed	0.002	200
Cardboard Backing (P2)	Cardboard	Processed	0.001	100
			0.037	3700

There are two scenarios for the transport, energy, length of life and waste sections of the tools.

SCENARIO 1: **THE PLUG IS MADE IN CHINA USING NON-RENEWABLE RESOURCES, USED FOR 5 YEARS AND IS PUT TO LANDFILL**

SCENARIO 2: **THE PLUG IS MADE IN SHEFFIELD USING RENEWABLE ENERGY, USED FOR 10 YEARS AND IS RECYCLED**

Figure 7: Data sheet for EU Converter Plug used for the CFP exercise

The Sustainable Minds tool was introduced first using a 10 minute video on the company website (Sustainable Minds, 2015b). They were then asked to complete a carbon footprint using the Sustainable Minds tool for one of the scenarios on the Data Sheet. During the workshop members of staff were available to assist with queries. The students were given 40 minutes to complete the carbon footprint analysis. Once this activity was completed they were asked to fill in a questionnaire, which was collected. The same procedure was then carried out for the Dirty Carbon tool, though guidance on how to use the tool was delivered via a prepared PowerPoint presentation.

Findings

Qualitative and quantitative data was collected from the questionnaires, observations and the answers given to an exam question on the subject. Key points of interest are presented below.

Questionnaire: Quantitative findings

Students were asked to rank eight statements on a ten point Lickert type scale where 1 = 'do not agree at all' and 10 = 'totally agree'. From a total of 42 students, 39 responses were collected for the Sustainable Minds tool and 38 for Dirty Carbon. Table 2 illustrates the mean numerical feedback that was given for each of the eight statements (ST1-8):

- Statement 1: I found the tool easy to use
- Statement 2: The tool gave me all the guidance I needed to use it
- Statement 3: The tool provided visual outputs that allowed me to understand the results
- Statement 4: The tool used language and terms that I understood
- Statement 5: The tool is accessible if I wanted to do another carbon footprint exercise
- Statement 6: The tool helped me understand what carbon footprinting was and how it applied to my work
- Statement 7: I would consider using the tool again as part of a future design task
- Statement 8: The information within the tool allowed me to understand the role of carbon footprinting

Table 2: Mean results from workshop feedback forms

	ST1	ST2	ST3	ST4	ST5	ST6	ST7	ST8
Sustainable Minds	6	6	6	7	6	6	6	6
DirtyCarbon	8	7	7	8	8	6	8	7

Both of the tools obtained good results across the board. However, in seven out of eight questions, Dirty Carbon scored a higher mean score than the Sustainable Minds tool. Only statement 6, saw a common score of 6, suggesting that the two tools were equally average at aiding understanding of carbon footprinting and how to they should apply it to their work. This was to be expected as the lecture was intended to provide this function, not the tools.

Statements 1, 5 and 7 drew the biggest difference in mean scores with the Sustainable Minds tool scoring 6 and Dirty Carbon scoring 8 in each of the three statements. These scores indicate that Dirty Carbon was easier to use, more accessible and would more likely be used again if a carbon footprinting calculation was required in a future design project. For statements 2, 3, 4 and 8 Dirty Carbon scored one point higher than for Sustainable Minds in each category, meaning that on average students found Dirty Carbon better at - providing guidance as to how the tool should be used; providing visual outputs (despite the fact that Dirty Carbon doesn't provide any specific visual outputs); using a more understandable range of vocabulary and establishing a better understanding of the role of carbon footprinting

Questionnaire and observations: Qualitative feedback

A rich but limited amount of qualitative feedback was provided through the questionnaire. This was particularly useful in aiding the further development of Dirty Carbon and as such will form the focus of the following section.

It was recognised that there were some issues with understanding the quantitative metrics within the tool - "the meaning of the units is still not very clear", suggesting the use of CO2e (Carbon Dioxide Equivalent) was sometimes misunderstood. However evidence from the answers given in the exam illustrated that it was actually understood. In a similar vein the students also identified that it would be useful to have a better understanding within the tool as to how good or bad the resulting carbon footprint output is - "a scale should be provided… to say how high or low the carbon foot print is". Both of these issues will be addressed in future iterations.

The lack of visual or pictorial feedback was highlighted as a negative aspect of the tool. This was not a surprise to the development team in light of designers strong visual preference and the considerable limitations of Microsoft Excel with regards to potential visual outputs. The students asked for "the ability to display the results as various graphs" or "to generate infographics, or organise the results in a more understandable way" as future additions. Though bar graph outputs will be added to version 2, further resources would need to be sought to investigate and develop the tool for a more flexible software platform.

The students reflected on the benefits of having the tools available online but additionally appreciated the fact that Dirty Carbon could be downloaded for use offline, meaning constant internet access was not a necessity. The fact that Dirty Carbon was free of charge was seen to be advantageous.

Despite the demonstration of the tool(s) and the instruction provided in the tool the students wanted "more help on what components to input where", "more explanation of each stage", "more notes and steps regarding [each] stage" and "more clarification for [the tools] application for industry". Suggested improvements included a glossary of terms (to assist in understanding the metrics and terminology) and a video tutorial, which can be revisited in the future. Interestingly however, during the workshops it was observed that the students had very few problems completing the carbon footprint (beyond a few technical issues which have since been resolved), which would suggest that the inclusion of reference material is not necessarily needed at this time. Previous experience suggests that they would be unlikely to read this guidance were it provided.

Feedback from the exam questions

The end of semester exams provided another opportunity to determine the success or otherwise of the new teaching package. A four part question on carbon footprinting was set:

- Explain in simple terms what carbon footprinting is.
- Explain the rise in popularity of the carbon footprinting approach within industry.
- What are the direct and indirect emissions of a car?
- Identify and explain the limitations of carbon footprinting?

All the students registered on the module (n = 46) chose to answer the question on carbon footprinting, suggesting that it was generally a topic in which they were confident. Of this number 43% attained a 1^{st} class classification (70% or more) and 20% attained the equivalent of a 2.1 (60% or more), for that question. Specifically it could be noted that the majority of students understood the limitations of the tool (which is was a key learning objective of the teaching package). Additionally there was good evidence of case studies and examples being used to support their answers supporting the belief that design students benefit from case study learning (Segalas, 2010). Overall it is believed that this demonstrated that the new teaching package had contributed to a high level of knowledge attainment regarding carbon footprinting.

Conclusions

This project has led to the development of a teaching package which introduces students to the concept of carbon footprinting and enables them to carry out a carbon footprint of a product using the Dirty Carbon tool, which outperformed the market leader in a teaching context.

Contrary to expectations, the Sustainable Minds tool (Sustainable Minds, 2015) performed well in an educational context, with both tools enabling students to conduct a successful carbon footprint calculation within a short space of time. It is important to recognise that the introductory lecture had a key role in increasing the students understanding of the subject (as demonstrated by the exam results) and fair to assume that without this, the reaction may not have been as favourable.

The simpler, more user friendly nature of Dirty Carbon was more popular with the students who indicated that they would be more likely to use it again during a future design task. The fact that it was rated consistently higher than the Sustainable Minds tool and that it is freely available, means that it is a useful addition to the tool kit of educationalists wishing to enhance their students learning of concepts associated with carbon footprinting. This usefulness is further enhanced by the fact that the structure of Dirty Carbon is similar in nature to existing market leaders and as such facilitates easy uptake between one tool and another, as was demonstrated in the workshop.

In conclusion, it is believed that the success of this project lies in the ability of the combined package of material – lecture, tool and workshop - to respond to the learning needs of design students, as outlined in the holistic framework.

Further work

Dirty Carbon is a prototype tool as and such will undergo further development. We plan to incorporate the interesting work of Carbon Visuals (2014) who create visual interpretations of carbon footprinting data. During the 2014/15 session it was introduced as part of the lecture and though it was clearly of interest and led to lots of discussion by the students, there was not enough time to include this as an activity in the workshop. The second semester will provide the opportunity for the students to consider visualisation of this nature.

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Carbon is available as free download (Microsoft Excel) from the Loughborough Design School website.

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