SUSTAINABLE INNOVATION THROUGH DATADRIVEN DESIGN USING LIFECYCLE ANALYSIS (LCA) METHODOLOGY

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ABSTRACT

The project sought to bring together fifty-four students enrolled on Nottingham Trent University's (NTU) BSc Product Design course and seventeen international exchange students (enrolled onto the European Project Semester - EPS) to work with industry partners, Alpkit and Design Matter with the common goal to reduce the embodied carbon of an existing Alpkit product; the Soloist tent. Both industry partners shared a common value of innovation through sustainability using Life Cycle Analysis (LCA) Methodology. Alpkit, a B Corp business had already established measures to track their social and environmental impact. Working with us, they sought to both improve their product credentials but also to support the education of young people to consider the impact of their decisions and design choices and the consequence on the sustainable values their product could achieve. The challenge that we set the students was to further push the boundary of one of their biggest selling products: the Soloist tent and explore design solutions that would further reduce its already streamlined carbon footprint, through the use of Life Cycle Analysis (LCA) methodology. The goal was to embed this in their learning to further add value to their design thinking in future projects. This presented an opportunity for students to learn how the use of product development and innovation can be gained not just through large shifts but also through many small gains, seeking granularity in design changes.

Keywords: Responsible innovation, collaborative/cooperative learning, design sprint, product design education, sustainable development

1 INTRODUCTION

A full product lifecycle analysis (LCA) is an in-depth exercise that looks at all of the sustainability factors that are attributable to a given product including, but not limited to water use, ore use, land use in addition to calculating pollutants such as carbon dioxide. An LCA would normally be undertaken by a specialist sustainability consultancy (SC) over a long period of time, with substantial collaboration with the product manufacturer and typically at a significant cost. For the European Regional Development Fund (ERDF) Sustainability in Enterprise project (SiE), and the Alpkit Design Sprint, the metric which was focused upon was carbon reduction. The Product Design aspect of the SiE programme offered Alpkit the opportunity to have the carbon footprint of one of their existing products assessed, followed by the product being redesigned or modified with the aim of reducing its carbon intensity. The carbon footprint of the proposed re-design would then be calculated to predict potential carbon savings. The aim of the project was to introduce students to the LCA process and embed the use of a toolset that would help them to consider the granularity of design changes and the impact that their decisions would make to reach the objective for the project; to improve the sustainable credentials of the Soloist shelter manufactured by Alpkit. The scope of the project meant that students would develop their skills through the utilization of tools used to perform LCA and critically investigate their own design solutions and specifications to improve the carbon footprint and further deliver benefits to the user with improved design considerations. Incorporating design sprints within education is well documented [1-3], providing a focused activity where new active learning tools can be successfully introduced. In addition, researchers have noted that innovative outcomes are enhanced through design sprint activities [4]. Having previously delivered a number of design sprints with larger groups [5], we included an immersive two-day lead in to introduce students to a new sector and new tool to support the LCA process. In recent years, sustainability education and the topic of LCA have become increasingly important in higher education institutions (HEIs). Despite the adaption of LCA education in curricula, there is still a gap in concrete examples of LCA teaching in the academic literature [6]. This case study aims to help fill this gap in the literature by sharing our teaching experiences on the subject of LCA.

2 DEVELOPING AN INTEGRATED LCA PROCESS

The process of conducting an LCA involved students identifying each material component, weighing and inputting data into an excel spreadsheet with preloaded values matching that of the materials. UK ICE material conversion factors for 2021 were used within the spreadsheet to provide carbon equivalent emissions. The conversion factors accounted for cradle to grave process including extraction, primary processing, manufacturing and transporting of materials to the point of sale. The emissions of each material were then added up and proportioned according to their relative weights, resulting in a value that took into account the product, packaging, use, repair and end of life. The main objective set for the project was to use carbon reduction as the key metric. Students also considered circular economy principles and the 5 R’s: Refuse, Reduce, Reuse, Repurpose and Recycle.

2.1 Development of bespoke tool

A sustainability consultant (SC) was assigned to the programme to develop the tool and to oversee the results of each product evaluation/redesign. To assess the carbon footprint of a product, SC would typically employ specialist software and use their access to dedicated databases to gather data. They would then use their expert knowledge to assimilate the data to calculate a carbon intensity figure. Such software requires in-depth training and specialist knowledge to use. SC therefore developed a simple screening LCA tool for the SiE and the design sprint based around an MS Excel spreadsheet. SC recommended that weight be used as a unit of measure and populated the spreadsheet with pre calculated carbon intensity figures by weight (carbon per gram) for a wide range of commonly used materials. Furthermore, carbon data for transport per mile (based on mode of transport) was included in addition to end-of-life carbon intensity data and specific carbon data for a range of manufacturing processes (e.g., injection moulding). This data was stored on a dedicated carbon worksheet. A simple user interface sheet was then designed.

The interface sheet required the designer/student to break the product down in to its component parts and populate the sheet line by line. The interface sheet used drop down menus for many of the cells, using material from the prepopulated carbon worksheet, allowing the student to easily and accurately populate the sheet. Once a line for a given component was completed, the spreadsheet would use the weight to calculate a carbon figure for each line/component. The interface sheet also contained formulas that would add all carbon figures together, giving a final carbon emissions figure by weight for the product, this figure would be clearly presented on the worksheet. In addition, a graphical worksheet was created that automatically created bar charts and pie charts to give a graphical representation of how the different components and materials used to make up the product proportionally contributed to its overall carbon intensity. A specific part of the interface sheet was dedicated to the product’s packaging and used exactly the same methods to obtain data and calculate the carbon figure. Finally, a data collection sheet was drafted, which laid out a standardised format for the bill of materials data that was required to undertake the screening LCA exercise. In the event that a material was entered on to the data collection sheet that wasn’t already included on the Screening LCA tool, SC would obtain the carbon data needed and add it retrospectively to the tool. Apart from the minor expected teething issues when the tool was first used, the basic design of the Screening LCA tool was successful, remaining the same throughout the SiE programme. It became apparent initially that more complex materials would need to be included and SC was required to add new materials to the carbon worksheet quite frequently, this requirement diminished as the programme matured.

2.2 Professional engagement

The project involved key contribution and engagement from industry partners Alpkit and Design Matter. Alpkit provided the challenge area and supported setting the brief with us. Design Matter provided training on the use of LCA and access to the tool which students used throughout the project. Working alongside us Design Matter tailored their existing tool to create a beta version embedded with data to support the project area, with values to reflect the materiality of the existing product and further additional materials that students may consider. Together we defined a baseline carbon figure for the Soloist tent which the students could use to compare their own product against.

2.3 Preparing and planning for the Project

In addition to the two-week project, we engaged the students in a half day tear down activity to introduce them to the level of detail required for the project and selected an additional Alpkit product to conduct a tear down on; the Qark head torch. We introduced the students to the granularity of design through accurately recording each component weight. Simple scales, with a resolution 0.01 grams enabled the students to complete a detailed Bill of Materials (BOM). Alpkit's disclosure of their level of granularity for their tear down analysis helped us to mirror this in our own process to achieve parity of information. Students worked in groups of six for the lead in activity to support their learning with the Qark torch tear down. The pre activity allowed us to trial how students worked in larger group but also test how fast they picked up the detailed level required of the project to give them confidence going forward.

Group size continued to remain large for the tear down of the Soloist tent due to the availability of product. However, for the design sprint, the project groups were scaled down; from group size of fifteen to group size of three to five students. The larger groups supported their collaborative learning at the early stage of the project whereby students self-supported each other sharing information and learning the toolset. Whilst the design sprint operated with smaller group sizes of three to five persons. Due to the nature of the design sprint process smaller group sizes supported focused activities whereby group members could progress quickly through the process with an intensity to drive outcomes.

3 METHOD

3.1 Project outline

The project was delivered over a two-week period. The first week involved a two-day immersion into both the brand and toolset. Whilst the second week involved a five-day design sprint process.

Week one, for our first day; students were split into two groups and rotated between Alpkit's head office and retail store located in Hathersage, Peak District, Derbyshire. The experience at the head office included a briefing describing the brand values of the company and comprehensive tour of the whole site including packaging, warehousing, assembly and machine shop where they were given an opportunity to make their own sewn product. The visit to Alpkit's retail store enabled the students to gain an insight into the brand expression and marketing of the full range of Alpkit's product. Students also visited a competitor retailer which provided insights into other outdoor brands and products.

Day two involved immersion into the LCA tool. Students were reintroduced to the LCA process and tool set and then asked to tear down the Soloist tent and input the data into the tool. Having completed the tear down of the Qark headtorch a month earlier the students had familiarity of the level of granularity and accuracy that was needed for the LCA.

For the tear down of the tent, students were divided into groups of fifteen, to spread the level of work, but further to collaborate and learn from each other. We found that the teams divided themselves in a number of ways based on interest of the activity and the level of involvement of individuals, sharing knowledge of ways of disassembly of components of the design i.e., stripping down seams, unpicking labelling. The tasks developed their teamworking, leadership and further organizational skills, managing many people across different tasks and handling allot of detailed data. Having previously defined the baseline carbon footprint for the project we used this to check the students concluding 'as is' LCA for the Soloist and provided guidance to adjust where we saw discrepancies, so that all groups were all aligned with the same baseline values. This baselining activity was critical for students to learn about the product, test the tool and work as a collaborative group. Having the two days upskilling not only allowed for focus to then design, but also enabled time for students to gain new skills on using the tool and also knowledge of a new sector.

The week-long sprint process followed, where students were grouped in smaller teams of groups of three. We shaped the first day to enable Alpkit to share insights to the rational on all elements of the detailed design of the Soloist tent and further manufacturing and specialist knowledge on materials across other product ranges to inform and upskill students. Day two; focused on further research and exploration of ideas, utilizing the tool to test materials to see the impact that they would have on the carbon figures. Exploration was also sought in regard to packaging and removal of components. Day three; involved further design exploration leading to development of a single focused idea. Day four; involved prototyping, compiling the evidence including their LCA data to fully justify their design proposals and fully communicate their idea. Day five; students pitched their ideas to the client.

During the sprint week, a Soloist tent was erected as a reference point for the students to further interrogate and check back against. Many students used this to check materials, construction, testing size and familiarity with the physical product to compare back with the changes they were making. As students moved through the design process the LCA tool was used to explore materiality and weights, used iteratively as ideas were developed/ explored. As students suggested new materials the toolset further was evolved, and new data imported into the excel spreadsheet so that it was up to date with the latest thinking and considerations of the students. The tool was kept live and evolved a number of times to ensure data was current to support students' enquiries. We declared a 24 turnaround for update to the spreadsheet, but this often was quicker due to the reduced timeframe of the project and the need to keep the toolset relevant at all times. The conclusion of the sprint resulted in students pitching their ideas in a five-minute presentation to Alpkit supporting their process and final proposal with data in which every student declared a carbon reduction.

3.2 Assessment of students' experiences

The sample of the study consisted of fifty-four students enrolled in NTU's BSc Product Design course and seventeen international exchange students enrolled in the European Project Semester (EPS) programme. The students were asked to make anonymous self-assessments of their sustainability knowledge and professional skills before and after the project. Data were collected online through pre- and post-surveys administered to the students between October 25 and November 15, 2022. The same questions were used in the pre- and post-surveys. The pre-survey link was shared in the online study room on the first day of the course, and all students in the class were asked to complete this questionnaire after the project was introduced. The number of students who responded to the pre-survey was 33. The post-survey was performed after the project with the same method and 31 responses were received. The questions in the surveys were asked using a 5-point Likert scale. The low engagement of the survey was a result of launching the survey face to face when the whole student cohort would not have been present. Despite keeping the survey open and promoted, it was hard to re-engage after the initial introduction, as all students were rarely present at the same time.

4 RESULTS

The overall success of the project has been of interest to many parties. The work has been leveraged into the development of a number of case studies to promote the methodology and promotion of engaged partners including the SiE team and Nottingham Trent University Courses. Moreover, the project has led to student ideas being selected by Alpkit to develop and progress to manufacture which has commercial benefits for both students and also industry partners. In addition, this project has been selected as a case study for the University to promote Work like Experiences (WLE) for students across all sectors to promote the growing embodied academic integration of sustainability tools and methodologies.

4.1 Student proposals

Each of the student's final proposals incorporated a number of carbon saving ideas. Proposals included the use of alternative materials such as banana fibres or Titanium Dioxide, replacement of polyesters and nylons, or magnesium Ze-62 in lieu of aluminium. Furthermore, design interventions included optimizing the performance and functionality of the product–to either integrate new systems and remove materials, improve on the weight of existing product or redesign of existing details.

Student group ten took a more original approach. By maintaining all the original materials, they redesigned the Soloist to reduce material consumption and product weight. They also further increased the overall useable space of the Soloist. Alpkit's feedback reflected the success of Group 10s proposal:

'These are principles we try to apply to any redesign in the outdoor industry: to decrease waste; decrease weight; and improve performance. We were so impressed by Group 10's redesign of the Soloist that we are now developing their ideas into products.' [Industry Partner 1]

Apart from the selection of Group 10's idea to further be developed as a prototype to manufacture and launch. The output of the whole group led to ideas that Alpkit have considered for their Soloist product and collectively presented an opportunity to achieve a total carbon reduction for the Soloist of 5.55kg (c.31%), resulting in a total potential reduction in their annual carbon emissions by 16849.8kg from just one product. The design changes that students proposed which would contribute to this included the use of recycled materials, eliminating waste in production, redesign of the pole hubs to reduce weight & consumption, tweak to dimensions and structure, improvement to packaging, prolonging useable life with improved care instructions & repair kits.

4.2 Student and industry feedback

Students have recognized the value of using date driven design to seek improvements in their projects and design in a more sustainable way. Student feedback highlighted:

'This experience ensures that I will have a greater understanding of the challenges and process of calculating what impact a product will have on the environment.' [Student A]

'I gained the understanding of how to properly use an LCA tool allowing me to reduce the carbon footprint of my own future projects to produce a more realistic piece of work.' [Student B]

Whilst industry partners commented:

'The Life Cycle Assessment of our Soloist tent has been a hugely beneficial process for us. Every project presented to us by the NTU students has provided us with invaluable knowledge that we can action immediately or plan for the long term.' [Industry Partner 1]

4.3 Comparison of pre/post-project results of student's self-assessment scores

Table 1 presents the students' mean scores for their self-assessments of sustainability knowledge before and after the project. The students had higher level of knowledge on life cycle assessment after the project (M=3.80, SD=0.13) than before the project (M=2.96, SD=0.15). Likewise, they had higher level of knowledge on sustainable materials after the project (M=3.74, SD=0.13) than before the project (M=3.39, SD=0.15). In addition, the students' responsible production and consumption scores were compared before and after the project, and their knowledge level after the project (M=3.35, SD=0.11) were found to be higher than that before the project (M=3.21, SD=0.16).

Table 1. Students' self-assessment scores for sustainability knowledge before and after the project

Sustainability knowledge	Before the project (N=33)		After the project (N=31)	
	Mean	SD	Mean	SD
Life cycle assessment	2.96	0.15	3.80	0.13
Sustainable materials	3.39	0.15	3.74	0.13
Responsible production and consumption	3.21	0.16	3.35	0.11

N - total number of participants; SD - Standard Deviation; Scale - 1- Not at all knowledgeable, 2- Slightly knowledgeable, 3- Moderately knowledgeable, 4- Knowledgeable, 5- Very knowledgeable

Table 2 presents the students' self-assessment mean scores for professional skills before and after the project. The students had mean scores for higher teamwork skills after the project (M=4.29, SD=0.11) than before the project (M=4.24, 0.11). Likewise, there was an improvement in their presentation skills after the project (M=3.83, SD=0.15) compared to the pre-project period (M=3.45, SD=0.17). There was also an improvement in the students' critical thinking skills after the project (M=4.03, SD=0.11) compared to the pre-project period (M=3.90, SD=0.10). However, no improvement was observed in their communication and innovation/creativity skills after the project compared to the pre-project period. This may be because the students already had high self-assessment scores for communication and innovation skills before the project, leaving little room for further improvement.

Table 2. Students' self-assessment scores for professional skills before and after the project

Skills	Before the project (N=33)	After the project (N=31)

	Mean	SD	Mean	SD
Teamwork	4.24	0.11	4.29	0.11
Presentation	3.45	0.17	3.83	0.15
Communication	4.09	0.15	4.06	0.13
Innovation/Creativity	4.00	0.11	3.93	0.11
Critical thinking	3.90	0.10	4.03	0.11

N - total number of participants; SD - Standard Deviation; Scale - 1- Very poor, 2- Poor, 3- Average, 4- Good, 5- Excellent

5 CONCLUSIONS AND RECOMMENDATIONS

Using LCA data, students found opportunities to further enhance and improve existing product resulting in proposals that have been prototyped for manufacture. The collaborative structure of the project which included large groups at the start of the project and smaller localised groups for the main sprint supported the students learning of a new tool and further developed their critical thinking as evidenced from the results drawn down from the survey.

Recommendations resulting from the delivery of this methodology include:

#1 Plan a pre-event tear down of a similar product to embed the granular level of investigation into the project and familiarise the students with the product sector.

#2 Schedule in a lead in day to develop awareness of the brand. Where possible this should involve a visit to the office / manufacturing site to understand the culture and operations of the business whilst also a visit to the retail environment (if applicable) this will provide a full end to end immersion and depth of the brand values that the students are required to understand in redeveloping an existing product.

#3 Schedule a day to embed the theory of Life Cycle Analysis (LCA) and further test its application through the use of the tool set in an exercise to undertake the baseline LCA for the existing product.

#4 Ensure the LCA toolset embeds alternate materials so that students are supported throughout the design process and iteration cycle of their design concepts. Such that the cycle of iteration flows freely with the use of the tool driving design decisions.

The conclusions drawn from evaluation and reflection have helped to inform future delivery of LCA methodology and embed this in further projects. An improved tool set is planned to be adopted to eliminate the interactive updates we had to undertake due to the nature of the data set and manual access to the excel spreadsheet. Further academic training is planned for the new toolset which will embed this further into our other course structures and projects; driving design through improvements in carbon foot printing will become embedded across multiple product design pathways and further sharing learning across departments as the tools set becomes embedded.

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