Higher Education Approaches to Engender Students' Environmental Consciousness in Electronic Device Design

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Abstract

Design briefs defined by user groups and their development into prototypes or demonstrators follows well established methodologies in both academia an industry. However, the infusion of an environmental context is yet to be fully established. It is critically important that this objective is achieved, so that the products developed promote positive environmental sustenance, follow processes that identify materials that are sourced from the most ecologically appropriate sources, follow a design methodology that leads to a set of candidate solutions that are all in one way or another environmentally sound, and finally the inclusion of an 'end of life' path which directly identifies re-usability or safe biodegradability.

This paper surveys the approaches Higher Education Institutions have taken in embedding environmentally conscious design tools, particularly related to electronics, into their students' curricula, and an informal audit as to how well their approaches engender sustainability of engineering and design consciousness in their graduates.

The paper draws on engineering, design, creativity, materials selection, innovation, product and industrial design in relation to electronics, in an otherwise broad sense. The paper also highlights examples of this approach at the Institute of Art, Design and Technology, Dun Laoghaire, within the Irish context of environmental policy.

1 Introduction

In this era of climate change and dwindling sources of both materials and energy, the nature of engineering is shifting to one based around conservation. The needs of protecting the environment and improving it are fast replacing individual or collective needs of users, based solely on themselves. In the area of electronics, there is some movement towards the appreciation that the sourcing of materials, development of processes, use of energy and manifestation of biproducts needs to be curbed in this age of insatiable data content. The chemicals and energy needed to synthesise and operate such equipment further adds to pollution and heating of the atmosphere. For instance, the development of data centres, with the computer manufacturing processes involved and high levels of energy expended as heat, raises questions on consumption and processes.

Electronic Engineering since its inception has relied on the application of scientific processes to extract and process resources in the main which are not naturally occurring. In addition, the enclosures for the products developed use materials that have been specific to support the electronics therein. Traditional engineering education in this area has focused on solutions that maintain the operation of such products, with the main considerations as regards environmental effects being electrical safety of the users or the public. Whilst

these aspects are very important, a growing awareness over the last quarter of a century is the fact that electronics manufacture in the complete process lifecycle can affect the environment detrimentally, in both the consumption of resources and the bi-products of the manufacturing and operational processes. In a wider sense, electronic systems function and maintenance maybe in conflict with the natural functioning and sustainability of the environment. The scope of influence and the assumptions made in development need to encompass a view as wide as possible. Indeed, it is fast becoming a social and ethical requirement to consider develop on this basis. Coupled with these technologies, is the desire to transmit data by high-speed wireless links, for instance the emerging 5G networks. There are concerns about the health effects of these high frequency communications links, effects on wildlife and the amount of atmospheric heating. Whilst these concerns may be unfounded, a more responsible and objective approach needs to be taken, with environmental sustainability firmly in mind before such schemes can be satisfactorily commissioned. Such an approach involves the foresight that can only be obtained through third and fourth level higher education.

Hence in higher education at both third and fourth level, students need to be not only aware of the need for developing sustainable electronic designs, but they need to develop tools to do so. Students should also debate the issues surrounding sustainability and the perceived effects of electronic equipment on climate change. Whilst there may be disagreement as to the whether such effects are taking place or their causes, it should be realised that many of their future employers not only do believe in the need to mitigate what they see as harmful effects on the environment, but also are investing heavily in resources, equipment and jobs to achieve this, with an expectation that their employees share the same vision. A spectrum of political, ethical and social perspectives comes to bear on the debate, with students having a clear idea of where they personally stand and the justified use of development tools.

Furthermore, the contribution of engineers to the fulfilment of sustainability is of course only one perspective. There is a spectrum of disciplinary contribution to this goal, for instance in business, psychology, social science, politics, art and media. The problem-solving skills gained by engineers in their education are not without parallels in these other disciplines. The communication through art and media of the importance of developing a sustainable planet is vital to galvanise action. These communication methods in themselves also needs engineers or engineering principles in their implementation.

With these broad considerations in mind, this paper sets out to gauge the progress in electronic engineering education with respect to planetary sustainability, and highlight particular initiatives in this area, within a cross disciplinary context such at the Institute of Art, Design and Technology, Dun Laoghaire, Ireland.

2 Survey of Programmes Incorporating Sustainability in Electronic Engineering

There are very few specific initiatives related to sustainability in electronics engineering education. The case has not been substantiated in this sub-sector. In the main, the closest match to such higher education engineering programmes are ones quite rightly related to energy management and sustainable electrical

power generation. There are also programmes which develop students' competences around civil and mechanical engineering infrastructure for electrical energy generation.

A comprehensive approach in the electronics sub-sector arises in the Nigerian polytechnic programmes (Mukhtar & Saud, 2019) and education to support sustainable electronic design in infrastructural electric power control, amongst other applications. In many cases electrical engineering programmes with sustainability included in their curricula are concerned with educating students to design power generation systems from renewable sources and civil engineering structures to match. Rochester Institute of Technology, USA has considered the aesthetics of sustainability in electronics, by including design processes to add a personal attachment dimension to an electronic product, whilst making it sustainable (Lobos & Babbitt, 2013). This approach is welcome, as the promotion of an emotional attachment within a product design will engender a change in lifestyle towards a more sustainably aware one. The University of British Columbia has embedded a sustainability theme in its electronic engineering programmes, with specific sustainability projects for students to learn through participation (Satti, 2018).

Much teaching and learning research into sustainable engineering effectiveness has involved examining methodologies and approaches. A specific example in the electronics sub-sector was conducted at California State University. A sustainability approach to electronic engineering laboratory work was developed, whereby students assess the environmental impact of every procedural stage of their experimentation and project work, through student self-reflection (Braun, 2010).

In the wider arena of engineering and sustainability, there are examples of methodological analysis of degree programmes in North America and Northern Europe. Researchers at Iowa State University recognises the broader themes of social, economic and environmental aspects in every engineering sub-sector and related area. They have developed tools to assess the teaching structures of such programmes, including the evaluation of using the Life Cycle Assessment (LCA) approach in design (Sharma *et al*, 2017).

An international group of researchers from North America/Northern Europe has evaluated the learning outcomes of sustainable engineering programmes, within the framework of the Tbilisi and Barcelona accords, the structure that all such higher education teaching should align with (Swanström *et al*, 2008). Researchers at Aalborg University in Denmark have assessed whether universities which offer sustainable engineering programmes, themselves work and promote sustainability at their campuses (Christansen *et al*, 2008). The paper finds that such a complimentary campus approach is most evident where a university offers a significant suite of engineering programmes in which sustainability is embedded, which implies that sustainability is more than just an addition to an existing teaching structure, it is a holistic philosophy within which such student opportunities can successful reside. The Technical University of Delft, Netherlands and the KTH Royal Institute of Technology, Stockholm, Sweden are two notable European examples of such a proactive campus-wide approach.

The National Strategy on Education for Sustainable Development in Ireland, 2014-2020 (Department of Education and Skills, 2014) does not specifically identify engineering in its policy, but does advocate a cross-disciplinary approach to sustainability at third/fourth level education and research domains.

The survey of electronics engineering related higher education worldwide, lead to an understanding that the embedding of sustainability principles into electronics engineering programmes would not be dissimilar to those in other sub-disciplines. Furthermore, in a cross-disciplinary environment, it is more about fostering attitudes, debate, habits and mindsets, without indoctrination political or otherwise. Knowledge of electronics technologies and their competent use is vital, however the responsible implementation in a sustainable context is the overlaying feature that allows students to choose the best projects to undertake based on these principles, as well as the staff in higher education to develop and foster research which contributes to sustainability or at the very least are neutral in their effects.

3 The Electronics for Sustainable Design (ESD) module at the IADT Dun Laoghaire

The author of this paper developed and delivered a new module to second year students at the Institute of Art, Design and Technology (IADT), Dun Laoghaire, Ireland, in January 2020. The module was an elective, offered to students in the Faculty of Film, Art and Creative Technologies (FACT), except those students already taking modules in electronics and engineering. Most of the students who took the module were from the Bachelor of Arts (Honours) programme. Students from this programme would be sourcing materials from different places such as recreate.ie, a storage facility for recycled or unused items, together with advisers on best use. Whilst as yet there is no specific strategic element to fostering programmes in sustainability at IADT, it is apparent from observing students' attitude towards their work, that there is a growing number who consciously have an ethos in using recycled elements in their installations, over and above the need to reduce costs.

In addition, students' interest included the gaining skills in electrical and electronics design and manufacture within an engineering context, that could be used in art projects, be it for example painting, sculpture, collage or a mixed media combination of such specialisms. A typical, basic example would be if a student wanted to incorporate audio-video aspects and need sensors and actuators to trigger the sources. A basic understanding of electronics as a springboard would satisfy their needs in this respect. In the context of sustainability, students wanted to know how they could take electrical and electronic components from re-cyclable equipment and use them in projects, in safe, orderly and design conscious manner.

A small number of students also enrolled from the 3D Design, Applied Psychology and Creative Computing programmes. Such is the eclectic mix of degrees at IADT that students' project work inevitably crosses over quite naturally between several disciplines.

The aim of the module was for small groups of students to use engineering principles to produce an artefact incorporating electrical or electronic components, which either improved sustainability or at least did not add to the carbon footprint significantly. The artefact had to be made using recycled materials and components only, where possible avoiding bought electrical and electronic components, plastics and chemical glues. Within the overall design process, the artefact's life cycle and re-use migration path had to be clearly identified as sustainable. It was possible that the students could produce an artefact that demonstrated the concept of a product that could improve sustainability, rather than the actual working model. It was made very clear from the beginning that sustainability should not be sacrificed over the aesthetics of the artefact. Thus, sustainable functionality was made primary motivation.

The output from the three-week module was for the team to produce an artefact and illustrated poster. As individuals the students had to produce comprehensive sketchbooks based on their own contribution to the project and learning experience in the module. Throughout students' written and oral communications, and subsequent actions, students were expected to converse in the language of sustainability and make all decisions primarily with this in mind.

Several workshops and field trips were arranged, in an order that best matched the author's experience in running such modules to predict students' needs at a particular of their work. The order is as below:

- Sustainability discussion session
- Workshop on the sustainable design cycle within a user needs context
- Sketching technique session
- Visit to sustainability themed exhibitions at art and science galleries
- General health and safety
- Electronics prototyping workshop
- Electronics manufacturing workshop
- Visit to IADT's workshops and digital fabrication laboratory
- Visit to tog.ie, a Dublin based maker space for creative electronics and arts projects
- Workshop to safely remove electrical and electronic components from equipment, for reuse
- Workshop to fasten materials together using the source materials, without glue or using specially made food-based glue
- Poster making technique session

Assessment rubrics, subject to examination board scrutiny, were developed for every aspect of the module, in alignment with the Quality and Qualifications (QQI) Ireland framework.

Whilst it is not possible at this time to reveal how well the students matched against the assessment, it can be said that those students who used engineering principles to produce artefacts which functionally improved sustainability, whilst using fully recyclable materials and components, with a clear end of life migration path, were most successful. It was clear that the most successful students communicated and acted in ways which took full responsibility for sustainability with their project and fulfilled the brief they had set. Indeed, the author of this paper learn much technically from the students as well as their embedded ecological motivations for all actions taken. It was also possible to see the gulf of understanding between functionality and sustainability that existed for some students.

With the students' permission, here is a selection of photographs of the artefacts at the final presentations, in Figures 1. and 2. below.

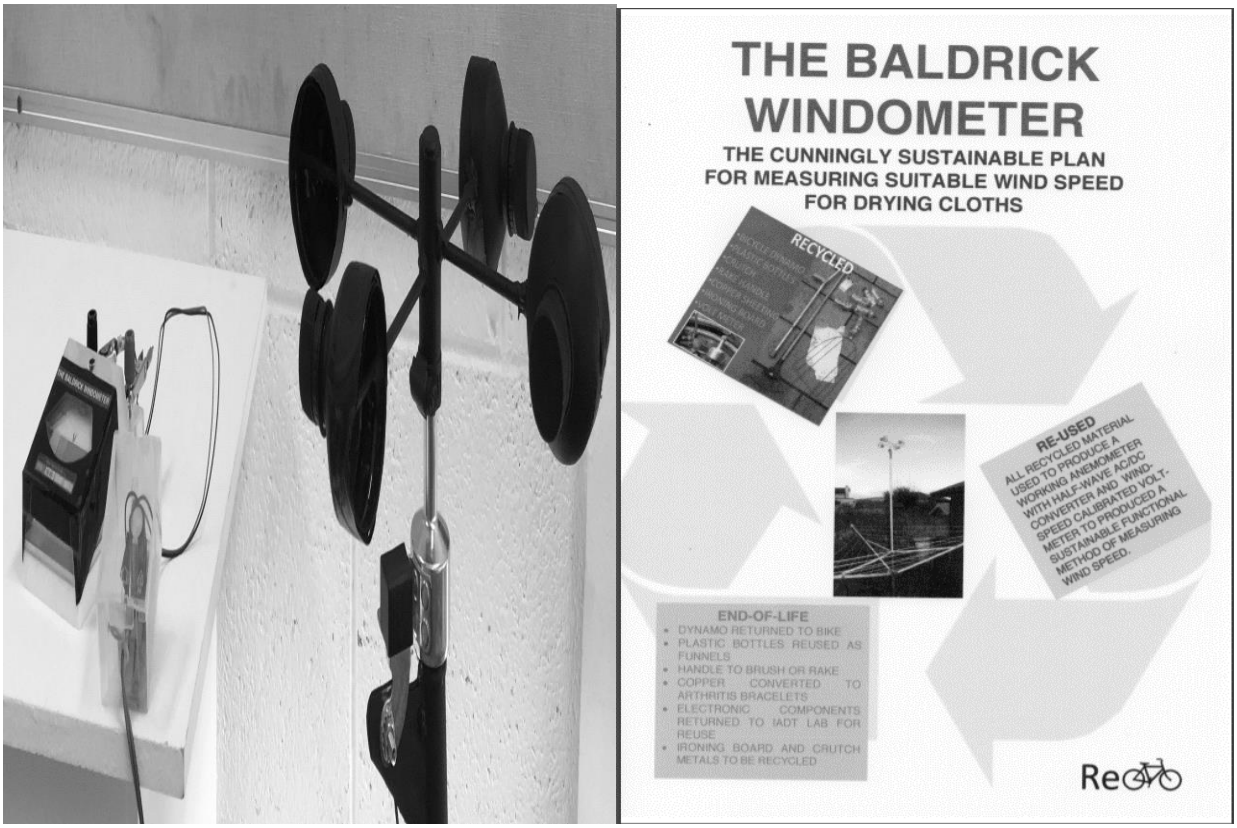

Figure 1. Anemometer with dynamo which activates a Met Eireann compatible Windspeed Indicator

Figure 2. Bubble making machine using eco-friendly washing up liquid and dual motor system

4 Proposed Principles of Sustainable Electronic Engineering in Higher Education

The survey of initiatives in embedding sustainability in higher education programmes, particularly those associated with electronics, leads to the following suggested criteria for developing taught modules in this area:

- Build sustainability into the whole life cycle of design-use-reuse All stages in the project and produce life and resurrection as another product need be audited for sustainability.
- Question at every stage of design, the sustainability of the choice made. This is a similar approach to the Life Cycle Assessment (Sharma *et al*, 2017).

- Ensure the product function and aesthetic motif encourages people towards a sustainable lifestyle.
- Approach the project such that aesthetics is a secondary aspect to sustainability
- Plan and implement the whole project development process, adopting sustainable processes at all stages of development, tools and environments used, as discussed by Braun (2010)
- Plan and implement throughout, in a practical way to use the least electrical power and assess the renewability of the sources, choosing one with the highest level
- Implement measures for ecologically safe disposal of any materials that could harm the environment, ultimately avoiding such biproducts in the first place

- Use of recycled electronic parts from other equipment or parts that have been manufactured from recyclable sources. Never overlook any discarded item without evaluating its potential for something else.
- Keep a record of all items being stored before ordering something new – the case for ordering new has to be justified in terms of usage in engineering educational products versus the effects on the environment if ordered as new.
- Consider using naturally degrading materials such as wood, metal, as opposed to plastic. If using plastic, ‘single use’ should be adopted.
- Use fastenings, made for instance from the parent material and non-toxic glue where possible

- Present projects in a way which uses the least electrical power and material wastage
- Follow the life-cycle plan in disposing of the final working product at its functional end of life, following a path component re-use.

5 Conclusions

The research into different sustainable engineering higher education programmes worldwide indicated that there is much more to do, in the development of approaches to teaching sustainable electronics engineering, and fostering this approach through projects and research in the campus environment. Whilst programmes may by piece-meal associate their programmes with sustainability modules, the most successful outcomes occur when there is a campus-wide permeation of these principles. Therefore a cross-disciplinary approach within the engineering discipline and outwards to arts and business sectors, would help to unify the overall goal of education students in sustainability.

The ESD module at IADT has shown the benefits of a very practical, creative and project driven approach to sustainable electronic engineering education can be implemented for non-engineering students in a successful manner, thus immediately creating a cross-disciplinary approach.

The principles of fostering a sustainable approach to electronic engineering in higher education can be summarised as a need for students to question the development approach at every stage, be fully conscious of their choices in materials and components up to the presentation stage, and secure an ecological end of life/re-use path.

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