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FROM ACADEMY TO INDUSTRY TO USER: ENGAGING STAKEHOLDERS IN SUSTAINABLE MATERIAL DEVELOPMENT

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Abstract. *The Art & Design Research Centre at Sheffield Hallam University has been working with the sustainability agenda for a number of years, with much of its focus being on the development of new, innovative materials that afford designers new creative opportunities and provide significant benefits for green manufacturing. This paper describes two such projects highlighting the role played by including key stakeholders in the material development process.*

The first, 'TTURA™' is a composite glass and resin material with some unique physical properties. The research team engaged with a variety of stakeholders to ensure the material would meet a wide range of end user requirements; trials included tests carried out by the waste glass industries, resin manufacturers, flooring contractors, architects, commissioning agents and end users. The second case study, at an earlier stage of development than TTURA™, takes the same user-centred research approach of engagement with stakeholders. 'BioChair' is a project exploring the possibilities for fibre-reinforced composite biomaterials, initially in collaboration with a government research institute. The research focussed on the development of a new bio-based polymer, with the aim being to understand the interactions of polymers with wood and pulp fibres and the effects on production processes and material performance.

1 INTRODUCTION

The case studies in this paper are part of two research projects undertaken by staff within the Art & Design Research Centre (ADRC) at Sheffield Hallam University. 'TTURA™' enables the conversion of waste glass into a useful, high value, structural building material with an appealing aesthetic quality of its own. Extensive development optimised the raw material to meet the requirements of the construction industry, and engaging a variety of stakeholders ensured the material would meet a wide range of end user requirements. The material went on to be granted a number of international awards and be used in high-profile, large scale city regeneration projects as well as forming the core products of successful new companies in the interior and furniture design industries.

In a similar development process, the BioChair project used a novel biocomposite in the creation of an injection-moulded chair for use in public spaces. As with TTURA™, a range of stakeholders was engaged to ensure the best possible outcomes. Laboratory testing confirmed material properties, and the biocomposite was trialed by polymer manufacturers and injection moulders at the same time as the potential market was explored with furniture manufacturers.

Further in-depth technical research is currently proposed to explore the use of other natural fibres such as flax in biocomposite sheet materials, with the long term aim of finding suitable applications in cleaner, greener products to meet consumer demand.

2 DEFINING INCLUSIVE DESIGN

The UK Design Council [Ref 1] offers the following definition: Inclusive Design is neither a new genre of design, nor a separate specialism. It is a general approach to designing in which designers ensure that their products and services address the needs of the widest possible audience, irrespective of age or ability. Two major trends have driven the growth of Inclusive Design (also known as Design for All and as Universal Design in the USA) - population ageing and the growing movement to integrate disabled people into mainstream society.

The terms Inclusive Design and Universal Design have overlapping definitions. The term Universal Design was coined by Ron Mace, founder of The Centre for Universal Design, as "the design of products and environments to be usable by all people, to the greatest extent possible, without the need for adaptation or specialized design." [Ref 2]

2.1 Principles of universal design as defined by the Centre for Universal Design

- Equitable the design should be usable by people with diverse abilities and appeal to all.
- Flexible the design should cater for a wide range of individual preferences and abilities. This may mean some choice in methods of use (such as right or left handed access).
- Simple and intuitive the design should be easy to understand, regardless of the experience, knowledge, language skills, or current concentration level.
- Perceptible the design communicates necessary information effectively to the user, regardless of ambient conditions or the user's sensory abilities.

- Tolerance for error the design minimizes hazards and the adverse consequences of accidental or unintended actions.
- Low physical effort the design can be used efficiently and comfortably with a minimum of fatigue.
- Size and space for approach and use appropriate size and space is provided for approach, reach, manipulation, and use regardless of body size, posture, or mobility.

2.2 Inclusive design principles as defined by the Sensory Trust [Ref 3]

- Integration, not segregation. Segregation serves to reinforce feelings of difference from the norm. Inclusive design benefits the widest possible spectrum of society.
- Working with, not for, people. Too often designers assume preferences and needs. Involvement of an inclusive range of users avoids mistakes and maximises success.
- The right to choose. It is important that people are sufficiently well informed so they are able to make their own choices. Sufficient information is crucial.
- Motivating by example. Good practice is more successfully encouraged by examples of positive design and solutions to common challenges.

3 INCLUSIVITY WITHIN THE DESIGN PROCESS

Designing and developing truly innovative products is a complicated process that draws upon the collective skills and knowledge of different designers, business people, engineers, scientists, manufacturers, retailer and end users. Different collaborative design methods are well documented and proven by, among others, IDEO and D-School at Stanford University. These methods demand constant re-evaluation, incorporating feedback from potential users. To validate the case studies described here, the proposed products were tested through working with academics, industry, manufacturers, contractors, architects and designers, commissioning agents, and final end users.

The development of new materials is a key output from this research. The products subsequently designed followed the principals of Universal Design. This paper describes the inclusiveness of the processes used to develop both materials, and outlines inclusive approaches that value the agencies of various stakeholders. It aims to show that a dialogic interaction that facilitates a multiplicity of perspectives is vital to the design process in creating engaging and meaningful outcomes for all concerned. For the authors of this paper, inclusive design embraces the notion that designing is an interpersonal, complex and layered process that includes the multiple roles people have.

4 RESEARCH METHODOLOGY

Both projects used a participatory action research methodology in which the key characteristics are that: the researcher is a participant and the main research instrument, it is cyclical in nature, involves action followed by reflection followed by informed action, and is concerned with producing change. This change is ongoing and the research is interested in input from participants/stakeholders. This allows for the continual development and improvement based on feedback from participants at regular points in the projects. [Ref 4]

5 CASE STUDY 1. TTURA™

Stockpiles of waste glass are expected to increase in the UK to meet the targets of the European Union Packaging and Packaging Waste Directive. This research project set out to explore different possible uses for waste glass in energy-efficient ways. It also explored the conversion of returned glass cullet into a useful, high value, structural material, and examined and developed potential creative applications. A key aspect was the involvement of a wide range of stakeholders, including the waste glass industry, resin manufactures, flooring contractors, architects, commissioning agents, and final end users.

The overall aim was to take samples of recycled glass through treatment and analysis to the point where it can be used in the manufacture of a value added new product. The resulting material, TTURA™, consists typically of 85% returned glass combined with 15% solvent-free resin, making it more sympathetic to the environment.

The project had four main aims and objectives:

- Find acceptable limits of impurities and particle size distribution of recycled glass
- Optimise the technology required for production and in situ applications
- Develop the physical characteristics of the products to required standards
- Develop end products to utilise the physical, optical, and aesthetic possibilities

A review was conducted to establish applications that would:

- Identify a volume market to maximise the use of waste glass in application
- Establish and nominate the range of test standards that the developed outcomes would be submitted to for validation.

This review revealed that a major use of non-solvenated epoxy resins (the primary nominated generic binder for glass waste) was within the construction industries - particularly flooring. As test standard requirements for flooring would validate utilising the composite in other products, this application was nominated as a control standard for the project.

5.1 Findings

Early trials used ratios of 70% glass to 30% binder. It became clear that changing to epoxy binders would allow greater glass ratios to be achieved.

A strategic aim was the utilisation of waste glass without expensive secondary processing. It was accepted that it would be necessary to remove sugar residues and paper from glass returned from the consumer waste stream, but testing revealed that all other contaminants could be accommodated without affecting the material's performance or visual appearance.

In establishing these parameters the volumes and particle sizes of the processed glass were reviewed in order to minimise secondary processing. Crude trials showed three particular mixes performed well in terms of material integrity, glass/resin ratios, surface appearance and manufacturing methodology. Tests on samples of these mixes by the Built Environment Research Centre and the Estates Department of the University confirmed the conclusions of the research team, and two sites for trial floors to be laid were offered. This provided an opportunity to assess the ease of application, user acceptability and performance.

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Figure1: TTURA™ used in city centre regeneration projects and furniture products.

The University required the composite met the relevant British Standards for Slip resistance, Impact resistance and Flexural Strength. The University funded a patent application to protect the developed knowledge before securing cooperation with a local specialist resin manipulator for the construction industries, Resin Building Products Ltd [Ref 5]. Two test installations were identified: a goods entrance at the University and the student refectory, which have now been in use for a number of years and established the material supply chain and end user validation, both short term and long term, in real situations.

5.2 Involving Stakeholders and End users

To validate the proposition of the research project and to gain knowledge to inform further work, the outcomes and protocols proposed were trialed and tested by the waste glass industries, resin manufactures, flooring contractors, architects, commissioning agents, and final end users. The trials confirmed the material management and supply chain scenarios, and the application by contractors on site proved more positive than expected, supporting enhancing the glass saturation in the composite. Surface finishing caused problems: traditional grinding protocols were not sufficient to deal with the hardness of the composite. Subsequent wear tests provided the knowledge for establishing in-situ finishing protocols. The trials also validated the composite by monitoring tonnage traffic (goods entrance) and footfall (refectory).

5.3 Project Outcomes and Impact

The developed composite was subsequently licensed to Resin Building Products Ltd and manufactured under the trade name TTURA™. It has been validated by internationally recognised research and testing centres and by industries associated with the control application. The outcome met the research aim in relationship to the potential volume usage of waste glass and supported EU and National government objectives for re-use of waste.

The dissemination of this research project led to high-profile collaborations with designers Thomas Heatherwick and Martha Schwartz, an International Design Resource Award in 2001 and a Material ConneXion award in 2004, improving the material's credibility and reputation. The work also produced a spin-off company 'Eight Inch Ltd' [Ref 6].

6 CASE STUDY 2. BIOCHAIR

Worldwide, furniture manufacturers that have investigated eco-sustainable furniture production have tended to focus on the recyclability of high-energy embodied technological materials rather than on the utilization of renewably sourced biopolymers that have a wider range of 'end of life' options, even including composting. Furthermore, research into 'sick building syndrome' raised awareness of the need for new design solutions and material formulations that will lead to improved and 'healthy' indoor environments. Previous design work undertaken between the researcher and New Zealand Crown Research Institute SCION had proved that small desktop items could be made using biopolymer materials formulated in New Zealand. The overall aim of the BioChair project was to investigate the use of biopolymers in the production of eco-sustainable products in the form of commercially viable office furniture designs. Working with Scion, polymer developments based on Scion's propriety 'know how' were further developed and tested for mechanical properties, commercial moulding possibilities and end of life options such as recyclability and composting. The biopolymer materials were also tested for structural durability when used with secondary materials such as solid timber. Previous work at Scion has demonstrated potential of such biopolymer materials in a range of applications, including some furniture components.

6.1 Methodology

Test: Data capture, Statistical Analysis, Material Development and Characterisation
Formulate a range of biopolymers and make samples for testing physical properties.
Test for: Strength, stiffness, impact, cyclic fatigue and durability.
Compare with properties of a reference polymer (20% glass reinforced nylon).
Define key properties for design considerations.

Design: Design Data, Material Selection, Product Design.
Research and analyse existing commercial furniture market and define target market
Research performance and safety standard applicable to target market seating.

Create a number of design solutions for seating that suit the defined target market.
Further develop design engineering via use of software and models
Create proof of concept 1:1 model (using appropriate materials and processes)
Market: Exploration of market potential for biopolymer commercial furniture sales via:
Exploration with end-user groups.
Exploration with plastic injection moulders.
Exploration with manufacturers.
Exploration with sales and marketing department.

6.2 Involving Stakeholders and End users

The outcomes of the research project were trialed by injection moulders and discussed with furniture manufactures, architects, interior designers, and retailers. Injection moulding proved highly positive. A batch of 50kgs of bioplastic was formulated by Scion and 43 5-star office chair bases were moulded using an existing tool. The trials showed that the biopolymer behaved differently to the bench mark material and that the existing tool, designed for 20% glass reinforced nylon, would need increased draft angles and that specific heating cycles would need to be developed to ensure biopolymer mouldings would not ‘stick’ to the mould.

A full size visualization model of the visitor’s chair was made using rapid prototyping techniques and utilizing timber for the legs. The model along with the injection-moulded components was used in discussion with architects, interior designers, and retailers. Discussions with these end user groups validated the design proposition.

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Figure 2: Moulding chair bases in bioplastic polymer, and a rapid prototyped model of the final chair.

6.3 Project Outcomes and Impact

The outcome of an injection-mouldable bioplastic met the research aims and objectives and dissemination of this research has resulted in discussions with furniture manufacturers who are interested in utilizing bioplastics for furniture production. Positive discussions have been held with plastic batch manufacturer Clarient, and will hopefully lead to a commercial agreement to formulate the material commercially.

6.4 Future Projects

'Improving Materials Properties using Modified Flax and Innovative Design' is a 12-month long collaborative project involving three partners: Sheffield Hallam University's Art & Design and Materials Engineering Research Centers and materials research company Netcomposites. It will build upon the researchers' work detailed above. Funding is by the Engineering and Physical Sciences Research Council under the scheme Engineering for Life. The project will adopt a new biocomposite material produced by Netcomposites, improve the shortcomings in the existing product using a new in-situ fibre modification technology, identify and develop initial design propositions of varying size and complexity and realise design propositions using the enhanced, modified-fibre material produced. This project will also utilize an action research methodology and include stakeholders and end-users throughout.

7 CONCLUDING REMARKS

To use Jevnaker's term [Ref 7], the two case studies in this paper can be viewed as a form of 'entrepreneurial mobilisation', which is currently the focus of many European Governments' remit to their particular university sector. From the starting point of a loose concept which clearly needed to be defined more exactingly, and no indication that there would be any application or market for a product, the two research teams initiated and led processes that were as much about mobilising and engaging groups of stakeholders as about research in the conventional sense.

Sheffield Hallam University's ADRC and more specifically the Lab4Living, offer a rich resource in inclusive design methodologies that have much to offer SMEs. Building on the experiences described in this paper and taking developmental thinking and methods in inclusive design into account, the centre aims to deliver sector specific outcomes for innovative future product development.

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