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Using interdisciplinary research project collaborations as a pedagogic tool to enhance learning and teaching: a showcase with low temperature fused recycled glass for a reception desk in the new academic building at the Swansea Waterfront Innovation Quarter.

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Summary - *Crynodeb*

This paper demonstrates how a collaboration between staff from differing subject areas within the University of Wales Trinity Saint David (UWTSD) at its Swansea Campus performed on a live project. The project was embedded in a research active field which investigated the feasibility of low temperature fused recycled glass as an architectural material, and invited undergraduate students to take part in the research within their discipline of study. The project's initial intentions were aligned to the amendments, which occurred in June 2015, in the Sustainability Principles for the SA1 Waterfront Development also known as Swansea Waterfront Innovation Quarter (SWIQ). These amendments developed opportunities to use the creative design and environmental skills of staff and learners within UWTSD for the development of the new academic building at the Swansea Waterfront Innovation Quarter. The delivery of project outcomes cumulated with three main aims; enhanced learner experience, formation of a research active and cross-faculty group and the development of a commercially viable product. This project was bespoke as it considered the changing environment and tells a progressive story of learner engagement, a collaboration between staff and external stake holders and demonstrates the first goal and the five ways of working from the Wellbeing of Future Generation (Wales) Act.

Bydd y papur hwn yn dangos sut mae cydweithio rhwng staff o wahanol feysydd pwnc o fewn Y Drindod Dewi Sant ar Gampws Abertawe wedi perfformio ar brosiect byw. Mae'r prosiect wedi'i wreiddio mewn maes sy'n ymchwilio'n weithredol, sy'n ymchwilio i ddichonoldeb gwydr wedi'i ailgylchu a doddwyd ar dymheredd isel fel deunydd pensaernïol, ac mae'n gwahodd myfyrwyr israddedig i gymryd rhan yn yr ymchwil o fewn eu disgyblaeth astudio. Roedd bwriadau cychwynnol y prosiect yn gysylltiedig â'r newidiadau a ddigwyddodd ym mis Mehefin 2015 yn yr Egwyddorion Cynaliadwyedd ar gyfer SA1. Yn sgil y newidiadau hyn datblygwyd cyfleoedd i ddefnyddio sgiliau creadigol, dylunio ac amgylcheddol staff a dysgwyr o fewn Y Drindod Dewi Sant ar gyfer datblygiad SA1. Wrth gyflwyno deilliannau'r prosiect penderfynwyd ar dri phrif nod: cyfoethogi profiadau dysgwyr; ffurfio grŵp ymchwil gweithredol traws-gyfadrannol; a datblygu cynnyrch sy'n ddichonadwy'n fasnachol. Bydd y prosiect hwn yn un pwrpasol am ei fod yn ystyried yr amgylchedd newidiol ac yn adrodd stori gynyddol o ymgysylltu â dysgwyr, cydweithio rhwng staff a chydweithwyr allanol ac mae'n arddangos y pum ffordd o weithio a nodir yn Neddf Llesiant Cenedlaethau'r Dyfodol.

Keywords: interdisciplinary-learning, sustainability, Wellbeing-of-Future-Generation-Act, pedagogy, commercialisation, arts and engineering.

Introduction

Circular economy and upcycling

Glass is virtually 100% recyclable and the use of waste glass has been developed into many different fields such as aggregates, filter beds and glass wool (Reindl, 2003). However, the new applications which are developed from waste glass end up as a down-cycled product. After the end-of-life, the material cannot be recovered or go back to the recycling stream again. This is something that the new paradigm shift towards a circular economy is trying to achieve (Kobza & Schuster, 2016; Pomponi & Moncaster, 2017).

A recent study by the Ellen MacArthur Foundation and the Waste and Resources Action Programme (WRAP) identified potential economic benefits of more than £2 billion each year to the Welsh economy. A further study by WRAP and the Green Alliance predicted that up to 30,000 new jobs can be created in Wales through development of a circular economy (Welsh Government, 2016; Ellen MacArthur Foundation, 2017). As an example of the energy saved through the recycling of bottled glass, one bottle would save enough energy to power a computer for 25 minutes. Considering that on average one family uses approximately 500 glass bottles and jars per year, this equates to an energy consumption of over 200 hours.

Furthermore, it is recognised that Welsh householders need to know where the materials collected from them are going and what it is being used for. This project focuses upon how recovered waste material can be utilised in fields such as architecture, innovation and construction. By demonstrating through a live pilot project involving a collaborative approach through the University's own expertise across Faculties and Schools, the learners were exposed to sustainability, development for future generation and circular economy through the act of an interdisciplinary learning and teaching focus group.

Aim of the project

The overall aim of this project was to explore how waste glass can be up-cycled to an aesthetically pleasing material which will be used as the main component for the reception desk at the new academic building at Swansea Waterfront Innovation Quarter. Research active staff from various disciplines came together to develop this interdisciplinary method to learn about a sustainable approach toward design, innovation and construction in an architectural environment. To ensure that agreed time-lines were met and a high-quality learner experience was observed, the overall aims of the live project were divided into separate facets of research, which complimented the experiences and skills of the learners. The staff evaluated the learner's progress through both informal and formal meetings (Pijl, 1992).

The exploration of the creative opportunities of this sustainable material was a major part of this project, in addition to the development of manufacturing processes that can contribute to low carbon, environmental benefits and a circular economy in Wales. End-of-life, and cradle-to-cradle approach toward the design development is at the heart of the design process and the development of this project will be through the implementation, explorations and product development of design thinking methodologies.

Objective

By bringing together fields of study such as art, engineering, construction, architecture and environmental conservation, the proposed learning and teaching project seeks to bridge these disciplines. An amalgamation of art practice and manufacturing processes has the potential to make positive impacts on the advanced engineering and manufacturing industry in Wales. It is a unique and timely opportunity to develop an interdisciplinary approach to learning and teaching with a focus to explore how the 'Five-ways-of-working' from the 2015 Wellbeing of Future Generation Act can be used as a catalyst for new thinking within teaching and learning. Wales is the first country in the world to put the wellbeing of future generations at its heart of core delivery and UWTSD have made it its mission to deliver this act.

Developing an interdisciplinary approach to learning and teaching in sustainability

Sustainability is of significant importance for the University with its multi-million pound development at Swansea Waterfront Innovation Quarter (Barry, 2016). The University is emphasising the use of locally sourced materials in the building to create a neighbourhood of academic activity at its core. Additionally,

it intends to attract companies to co-locate with the University to foster knowledge, develop skills, support existing companies and attract new investment into the region. However, it is also highly unusual for a construction company that is building a new academic campus to agree and to support such a speculative development of a reception desk made from a new and novel recycled glass material. The recycled glass material is yet to be manufactured and commercialised, as well as a project which is driven by undergraduate dissertations (University of Wales Trinity Saint David, 2016).

The project was underpinned by the four pillars of sustainable development. Environmentally, it demonstrated the collaboration between UWTSD's teaching and learning practice, Kier Group Construction Company and Stride Treglown Architectural and Design Practice. It also demonstrated that low carbon manufacturing is a high priority and contributing to the low carbon mission of the Welsh Government. Moreover, wider cultural benefits arise as the creative industry stride to create an aesthetically pleasing architectural material which is a sustainable alternative for architects, interior installations and furniture. From a social perspective, it created a positive impact through the facilitation of a collaborative partnership which is working towards a more sustainable future between industry and several different HE disciplines, and it also allowed for provisions that encouraged business start-up and creating jobs within the circular economy. Additionally, further benefits were aligned with the first goal of the Well-being of Future Generation Act, 'A Prosperous Wales' with a sustainable product to market.

Following this Act, prevention and long-term-thinking is at the heart of all decision making, enabling the consideration of both end-of-life of the product and demonstration of how a waste material can be up-cycled and re-introduced into the circular economy. This project also showcases how the University's reputation on environmental and sustainability issues can complement the traditions of Art and Design, product technology and makers artistic vision and mutually reinforce each other.

The supporting aspect of developing a learners and teaching focus group has also been influenced by researchers like Elena Antonacopoulou (2000) who published on employees willingness to learn and take responsibilities for their personal development, as well as the interaction between the organisation and the employees personal development initiatives. Hameed & Waheed (2011) proved that the success or failure of an organisation relies on the employee performance and that there is in the organisations interest in investing in their development. This interdisciplinary project are underpinned by the relationship between learning, skill growth, self-directed, and learner's attitude and their performance variable. It was, therefore, viewed that the learner's performance will affect the interdisciplinary group's outcome and success.

The benefits to the learners

The benefits to the learners engaging in such a project consists of many characteristics that are advantageous to their development within their field of study in addition to their professional values and practice. The integration of the group naturally facilitated discussions and mentoring between staff and learners from numerous subject specific areas which has beneficial pedagogical characteristics to the learners. The delivery techniques and means by which assessment is conducted formatively within subject areas naturally differ as they have evolved to be fit for purpose. The group dynamics encouraged tutorials between staff and learners from different subject specific areas and as such, the learners benefitted from pedagogical techniques that were often unfamiliar to them, yet differentiated according to their individual needs and preferred learning style. This enriched the learning experience and encouraged creativity and aspirations which reached beyond the realm of their chosen discipline.

Since many aspects of the project were learner led, it naturally followed a facilitated and self-discovery mode of delivery. However, to gain a robust experience of research and development, it was necessary to ensure that learner activity was diverse and engaging (Black & Wiliam, 1998; Black et al., 1998). Each facet of the project required the learner to work as an individual, within a pair or group, tutorials with staff and disseminating findings in both orally and in written contexts. Skill development in communication, working as an individual, improving upon one's own performance and working collaboratively are additional key features. Moreover, participation in a collaborative environment as described here, yields additional benefits to the staff members since observing a variety of pedagogical techniques in a capacity of sharing good practice allowed self-reflection and the potential to integrate these techniques into further teaching practice.

Activity Developed

The learning activity was carried out at the University by lecturers, research staff and learners from Swansea College of Art and the Faculty of Architecture, Computing and Engineering (FACE). The core focus on the activity was to develop and construct a reception desk from low temperature fused recycled glass, which is to be situated in the new academic building at Swansea Waterfront Innovation Quarter. The main contractor for this development was Kier Group and the architectural company was Stride Treglown. The activity comprised of different stages: planning, monitoring, and review.

Planning

A project team was created with the purpose to manage this activity, initially formed by participating supervisors, and led by Dr. Tyra Oseng-Rees. Initial meetings consisted of an introduction to the recycled glass material and the proposed project outline that was to be delivered to the industrial partners. The initial proposal involved learners in a collaborative live pilot project aimed at developing the recycled glass material to be fit-for-purpose and ready to be installed in the interior of the new academic building. According to the available resources, timescale and expertise, it was decided to work on the design and manufacturing of fused recycled glass material and to utilise this as the main component of the reception desk. The project was designed to be delivered in two phases lasting over a two year period. Phase one ended at the end of academic year 2016/17 with the delivery of the learner's dissertation. Phase two ended with the completion of the academic building May/June 2018.

Upon definition of the live project, facets were identified that facilitated the development of short term projects with learners that could contribute to the common global purpose. These short term projects could refer to undergraduate learner dissertations or projects in different disciplines to be completed in the form of assignments or practical exercises in their modules. These proposals were grouped in four main areas: engineering, material characteristics, design and environmental conservation.

The project was tailored to each of the disciplines of study and presented to the learners from the School of Engineering (SoE-FACE), School of Architecture, Built and Natural Environments (SABNE-FACE) and Swansea College of Art at the beginning of term September 2017. A general view of the project was given and specific short term projects were proposed. Learners also had the opportunity to develop their own proposals and a total of seven dissertation projects were initially proposed with their corresponding learners engaged:

- Engineering
    - Construction of bespoke glass crusher
- Material characteristics
    - Impact resistance analysis
    - Cost Analysis
    - Material quality certification
    - Carbon footprint
- Design
    - Aesthetics, texture and design development
    - Development and making of desk carcass and fittings

These projects are explained in details below.

Student projects

After introducing the live project to learners within the disciplines of art glass, engineering, environmental conservation and construction, ultimately six undergraduate projects were formed. The learner projects were developed to be self-contained dissertations, or in other cases as part of a module assignment in their corresponding disciplines. Each project was designed to achieve an integral part of the overall aims of the study in addition to realising the construction of a reception desk which is manufactured from fused glass.

Glass art project. The final year project for the glass art learner was to explore the aesthetic opportunity of the fused recycled glass. The learner was aimed to meet the requirements from the interior architect and

to respond to the project brief from the external group in terms of texture, colour and reproducibility (Figure 1).

Figure 1 - Aesthetic exploration of fused recycled glass by Jana Kleprlikova.

Redesign of glass crusher. The engineering learner was tasked to design/re-design a glass crusher that would meet the needs of crushing bottle glass in a small scale production run. The learner was tasked to look into products on the market, the best crushing mechanism which also avoided any metal contaminations that arise from the use of soft steel for crushing bottles (Figure 2).

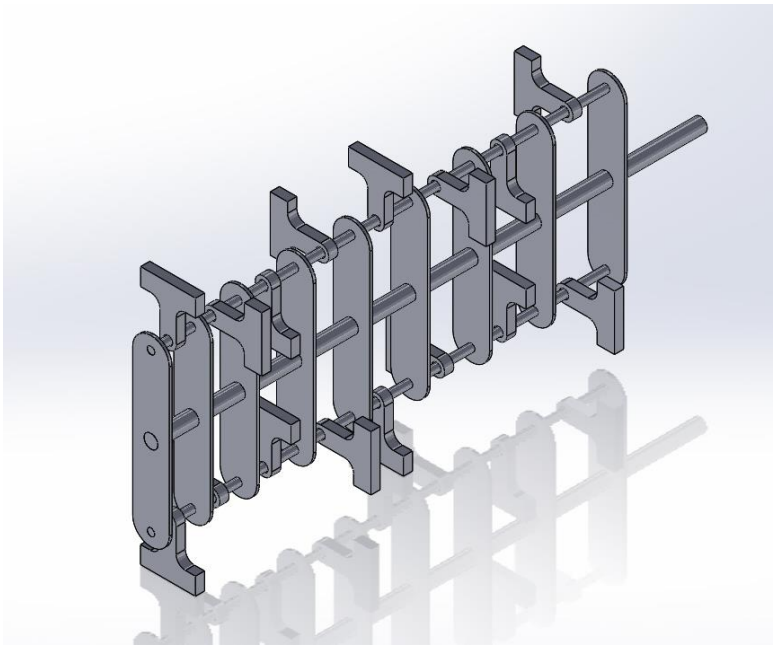

Figure 2 - Engineering drawing, hammer configuration by Robert Price.

Impact resistance procedure. The third learner was concerned with discovering the impact resistance of the fused recycled glass and to compare this to known materials. This project arose at the request of an architect and additionally required the design and fabrication of a test rig (Figure 3). The research from the learners dissertation were published at the 19th International Conference on Advanced Architectural Engineering and Construction Materials, Paris 2017 (Halley et al., 2017).

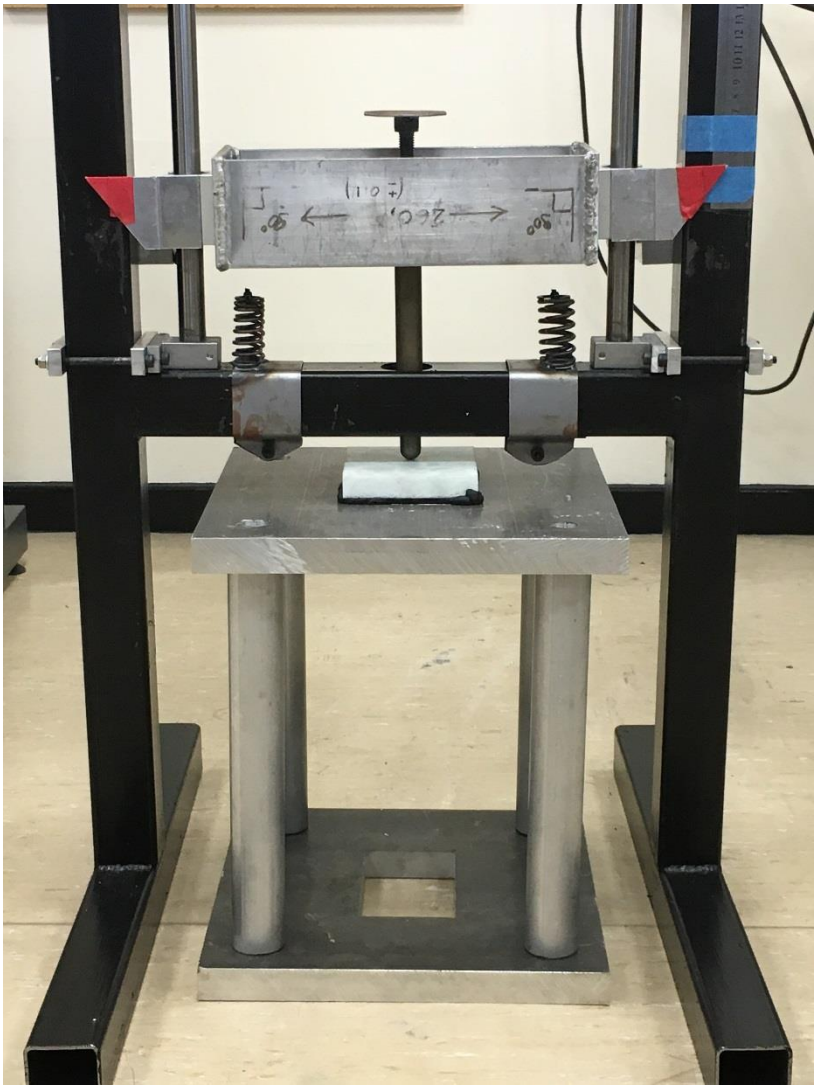

Figure 3 - Impact testing jig by David Halley.

Carbon footprint. The fourth learner was looking into the carbon footprint of the fused recycled glass manufacturing. The learner had to decide about the best approach and analyse different energy consuming processes and associated carbon emissions.

Material quality certification. The fifth learner was tasked with materials quality certification so as to analyse the process for a new material to be introduced in the market, in this case the fused recycled glass, and be able to certify the manufacturing process quality.

Cost analysis. The sixth student focused on cost analysis. The learner had to transfer this project from academic research onto a product to market and scaling the manufacturing process up to large scale. The life cycle cost analysis approach was first indicated as a reference to it.

Mock up carcass design. Lastly, as a late onset to the project, there was a first year architectural learner who was tasked with the design and making of a carcass that holds the glass panels. This focused on end-of-life usage in addition to fabricating a dry fixture capable of holding the panels without any glue or residue (Figures 4 & 5).

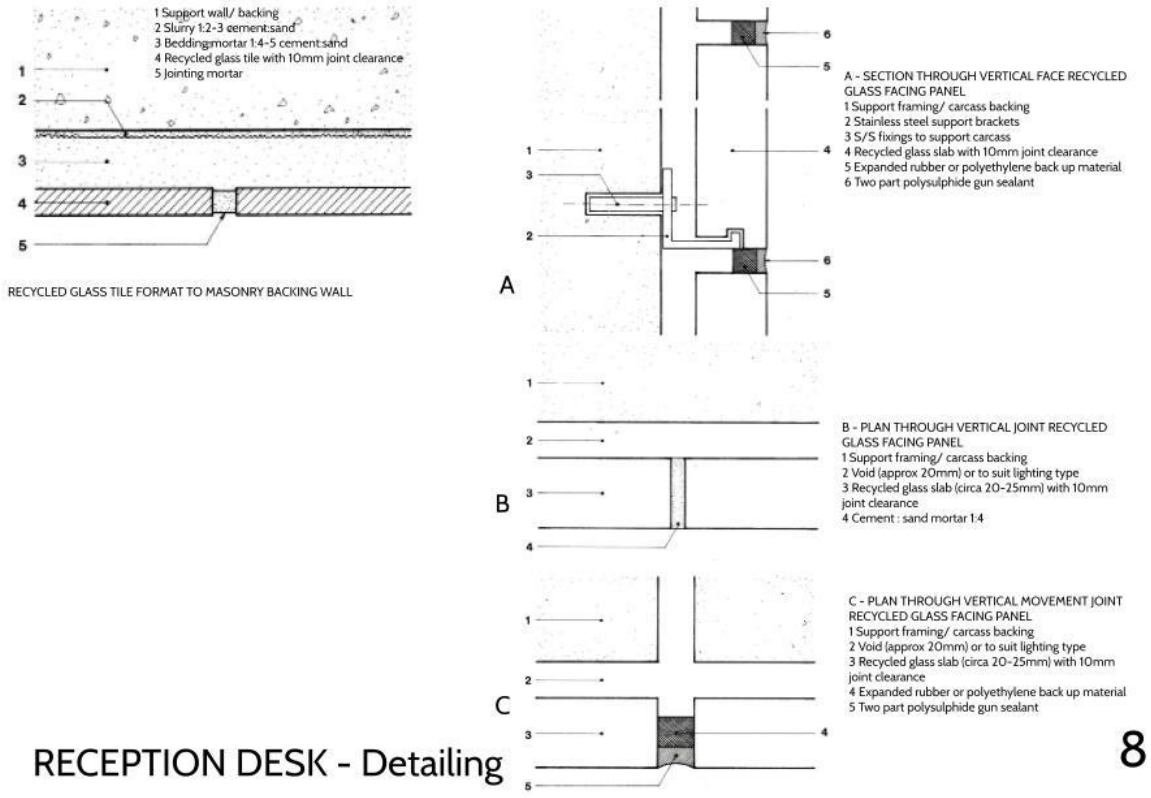

Figure 3 - Technical drawing for dry fixing of recycled glass panels by Ian Standen.

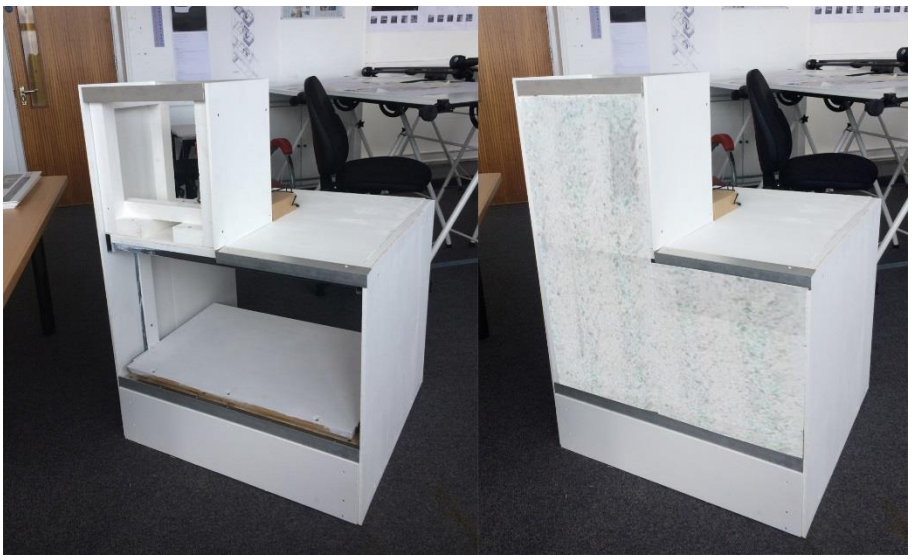

Figure 4 - Carcass model made to hold recycled glass panels, made by Lee Chandler.

Monitoring

An initial meeting was held in October so that all staff and learners could meet. The basis for organisation was established in the following:

- Each project would be developed individually by the learners with the focus on their subject specific area. A member of staff from the subject specific area would be assigned to be the main supervisor of the learner so that he/she could facilitate the study within its agreed boundaries.
- Some projects were linked and a close collaboration between the learners was encouraged.
- Periodic meetings were established so that progress of the global project could be monitored and decisions taken.
- Progress was also reported to the company partners. Dr. Oseng-Rees was integrated in the SA1 Project planning meetings (Fixed Furniture & Equipment) for the design development and additionally, the supervision staff were also in contact *ad hoc*.
- Different professionals from the company partners also participated in these project meetings, sometimes to discussions design and texture of the glass panels, other times to discuss the material specification. Close collaboration with the SA1 Design Team was essential so that learners could directly ask questions occurring during the design stage and receive comments and feedback from these professionals.

Other external professionals and researchers in specific areas were introduced to the project to participate in the development of several parts. One example was the development of the process and test-jig for impact testing the fused recycled glass. Although these projects were supervised and monitored, they were facilitated so that the learners retained their autonomy and ability to make independent decisions.

Review

A questionnaire was developed to be answered by staff and students who participated in this activity (see Appendix). The questions were focused on the feedback received from each individual participant, highlighting positive aspects and areas of improvement. Additionally, it also provided an opportunity for participants to make suggestions about further learning and teaching development which could be employed in successive years.

Challenges. Despite establishing meeting dates with enough time to be prepared, it was very difficult to find available dates for everyone to meet due to teaching commitments and fixed timetables. In fact, a meeting where all stakeholders were present was never realised. For this reason, the allocation of a personal supervisor for each learner was essential to be able to follow track of all projects. The project leader was responsible for keeping contact with every supervisor, coordinating and detecting any issues during the development of them.

Not all supervisors achieved the same level of communication with learners or participation with the project due to other commitments and heavy teaching loads. The project leader had to help and take charge of some learners on occasions. Despite that, the final results were satisfactory according to the initial expectations and it was possible to develop the first stage of this project.

Learners had the opportunity to make their own proposals, but at the same time the project required specific developments to be able to adapt according to the customer needs. The combination of these interests was difficult at first, but finally it was possible to define specific projects for each student and common elements of collaboration between them as well as valuable results for the company partners.

Special circumstances were identified with two learners as they were not progressing at an appropriate rate. Several support sessions were arranged to rectify these issues, however, incompatibilities with timetabling and jobs outside the University often proved difficult obstacle to navigate. Finally both learners decided to leave the project.

The glass art student also changed the project focus from working to meet the design criteria for a reception desk, to meeting the request for an art installation in the same building, although still working in the fused recycled glass material. This was in line with the programme of study and the student's final year degree was achieved successfully. However, this added challenges to the overall live project and the project manager had to deliver the final design of the fused recycled glass material.

Funding

This project was initially designed to fit around learner projects and funding that already existed for students with equipment that was readily available. However, an early identification of a need for the funding of materials for the glass crushes became apparent. This was agreed at the beginning of the live project by the SA1 Project manager to fund up to £1000. As the individual student projects progressed, it was identified that further small amounts of funding were needed. This was achieved through an internship scheme run by the University. Additionally, some specific materials were needed to finalise the design of the impact test jig and after a project proposal by the student the SA1 project manager agreed to pay the difference in cost.

Summary of feedback

Meeting the requirement of the first goal in the Well-being of Future Generations (Wales) Act

This project aimed to meet the first goal in the Well-being of Future Generations (Wales) Act, 2015: A Prosperous Wales. The first goal reads as follows:

> *'An innovative, productive and low carbon society which recognises the limits of the global environment and therefore uses resources efficiently and proportionately (including acting on climate change); and which develops a skilled and well-educated population in an economy which generates wealth and provides employment opportunities, allowing people to take advantage of the wealth generated through securing decent work'*.

This project included aspects that showed relevancy for sustainable recognition and aimed to use low carbon manufactured recycled glass, with a circular economy approach, locally sourced materials and industry collaboration. Additionally, it was based on cradle-to-grave design approach, demonstrating a showcase to Welsh and British householders how waste glass can be up-cycled to an aesthetically pleasing material, through an interdisciplinary and collaborative learning and teaching approach.

The project demonstrated through the five ways of working at the Act:

- Long term view
    - Provided more lifelong learning skills for future learning/teaching in interdisciplinary projects and sustainable development
- Prevention
    - Close supervision and project flexibility helped to detect arising problems and change learner´s projects or adapting to new circumstances
    - Members of staff were prepared to 'walk the extra mile' if needed
- Integration
    - Learners had the opportunity to be supervised from staff with different expertise areas
    - Learners from different backgrounds were integrated into the same project for collaboration between them
- Collaboration
    - Collaborative work between Schools and Faculties in the same project
    - Collaborative work between learners across different disciplines
    - Collaborative work between external companies, the SA1 Project management team and staff and learners of UWTSD
- Involvement
    - Learners could benefit from participating in a life project with real customers
    - Learner contribution were perceived to be very positive by stakeholders
    - There was better understanding between aesthetical and engineering aspects

The collaboration developed addressed the following goals:

- A low carbon footprint its manufacturing process was demonstrated
- A circular economy approach for design and manufacturing was evident
- Industry collaborations demonstrated
- A range of new aesthetics and textures of the recycled glass material were developed
- It demonstrated the five ways of working according to the Wellbeing of Future Generation Act

- The results addressed on the first goal of the Wellbeing of Future Generation Act, A prosperous Wales
- It was possible to carry out material characterisation in terms of strength and stability
- The opportunity for a business start-up
- Learners' experience was enhanced with the live case study and their dissertation was applied to industry
- Academic publications of results

Continuation of further projects

The development of this activity proved an encouraging experience for learners as well as lecturers and other participating staff. Further projects that are suitable for learners in consecutive cohorts are identified. Below are a few different contained projects that could be developed into additional dissertations within various fields:

- Aesthetics: further to exploration of the material in aspects such as colours, transparency, textures, etc.
- Supply chain: source of raw material, processing the waste glass making it ready for manufacturing
- Carbon footprint: detailed study to analyse different processes to reduce the carbon footprint
- Impact testing: continuation on the research by expanding the test parameters and repeatability.
- Business start-up: introduce product in the market, marketing, and to demonstrate the viability and impact to the construction industry as an alternative sustainable architectural material

Conclusion

It was possible to demonstrate that an interdisciplinary collaboration was necessary and helpful to successfully investigate the feasibility of fused recycled glass for the application of a reception desk. The participation of learners from different disciplines enriched the project by facilitating a new vision to be able to enhance the learning and teaching from a learners' perspective.

Additional efforts were needed to integrate this live project into the learners' academic studies. Difficulties presented themselves as there were numerous stakeholders with varying goals and, therefore, a robust project management strategy was necessary to ensure the overall success. Moreover, the diverse range of mini projects and the positive environment which evolved as a consequence of this group also nurtured an environment that was conducive to learning, as sharing good practice was beneficial for both staff and learners alike. Furthermore, the results were very positive for the participants and created a partnership framework that can be useful for other future collaborations between departments inside the University as well as with the external partners.

This project demonstrates the relevance that engaging in live projects has to offer learners' and their learning process. Additionally, the experience they receive by participating in such collaborative efforts that is focussed upon a common goal is of high value for future research engagement as it mimics 'real' research environments.

"*We found the process of developing the reception desk with Tyra to be a collaboration in the true sense of the word. She and her team became an integrated part of the Design team, and brought an inspiring, fresh approach to the work*" Pierre Wassenaar (Director, Head of Technology and Innovation, Stride Treglown).

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Appendix

Fused recycled glass project

Feedback sheet – staff/students

Explain briefly your participation.

Specifically, can you describe positive aspects and the challenges about the following?

Interdisciplinary work/Team work

Engagement of students in the project

Link to your programmes teaching/learning

Industry links

Budget

Other you think that are relevant

Do you want to continue this project next year? If yes, in what way?

Would you like to add any other comments