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WASTE AS A STARTING POINT – HOW TO EDUCATE DESIGN STUDENTS TO BECOME ACTIVE AGENTS IN CLOSING MATERIAL LOOPS

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ABSTRACT
The Waste to Design project gives students a framework to do their thesis on trying to use industrial waste for new production. The first year of the project saw four theses, shedding light on the design process required for this type of work. The most common difficulties observed were uncertainties about material properties, production possibilities and regulations. This made students strive to connect and collaborate with people from other backgrounds, suggesting that improving cross-disciplinary collaboration skills in design education would facilitate this type of work.

Keywords: Industrial waste, design process, closed-loop

1 INTRODUCTION
Design has an active role to play in helping society strive for a sustainable use of material resources. It has been suggested that this can be achieved by maintaining materials in closed loops. This means that instead of discarding a product after its use, it is sent back to be reused, refurbished or recycled [1]–[3]. This casts new light on discards, turning them into input for new production. When this is acknowledged while designing a product, developers can plan how to take back and reuse their material resources (e.g. Ricoh printers [4], Wilkhahn office furniture [5]). Unfortunately, most production is not being done in this manner, nor are the take back systems needed often in place, resulting in still increasing waste volumes worldwide [6].
Up until now design has not necessarily aimed at taking in waste in a systematic way. This is reflected on the fact that there is no methodology developed to facilitate designing with waste. The project "From Industrial Waste to Product Design" (W2D) is a first approach to investigate what methods can be useful for this task, while illustrating how this process is done. If a methodology can be developed it can be used in design education to give the next generation of designers better tools to actively engage in recovering discarded materials into society's material flows.
Even though designing with waste is not novel, there has been little documentation of the methods used to achieve attractive products from discarded materials. In order to be able to review the process of designing with waste closely, the W2D project presents this challenge as a theses topic for last years students of design programs. As a starting point the students have to use existing industrial waste (that is currently land filled or incinerated) for new product development. This poses a different setting for the design process. Normally, design starts from a specific product briefing to be fulfilled or a defined user need to be satisfied. In this case, the design process takes off from a material fraction out of which a wide array of products could be developed. Most of all, the project aims to investigate the challenges that arise with this different point of departure and to see what can be done to help designers in this task.
The W2D project has been running since fall 2012, and will be finalized in spring 2015 under the Mistra Closing the loop initiative [7]. It is collaboration between industrial recycling company Stena Recycling, engineering consultancy Semcon and Chalmers University of Technology. Design students are asked to do product development using one of the materials offered as main input for new production. The materials they can choose from are industrial discards that Stena Recycling receives that currently do not have a fully functional recycling market (e.g. PVC cable sleeving, PUR foam). The project gathers experts from industry (Semcon and Stena) and academy (from the design and material fields at Chalmers) to provide supervision time for the students that decide to get involved.

The first year saw the work of two bachelor and two master theses. This article collects the data gathered from reports, logs, interviews and the experience of supervising these students in order to highlight the lessons learned during the first year of the program. This knowledge will be used to better prepare the next group of students in the program, but also to shed light on what aspects become relevant for industrial design education when we expect designers to become active agents in closing material loops.

2 W2D PROJECT SET-UP

While preparing to receive the first group of students for the project, the authors investigated what methodology designers use when working with waste as a starting point. Even though several products made from waste were studied, no reference to methods or design processes was found. The examples of designs made from waste were studied further and categorized in a separate article [8].

Later, a review of the traditional design process was done in order to propose a process structure that could help designers to work with waste as input material. The proposed structure comes before the normal design process and is divided in three sections: research about the material, idea generation for application areas and a screening stage. This would result in a product idea that can be taken forward with a traditional design process [9]. A traditional design process was considered a funnel, where different stages of idea elaboration are followed by reduction of ideas, arriving after several iterations and levels of detail, to a finished product [10], [11]. This proposed process for designing with waste was presented in an article [9] that was shared with the students involved in the W2D project at the beginning of their thesis work. Figure 1 gives an overview of the process proposed.

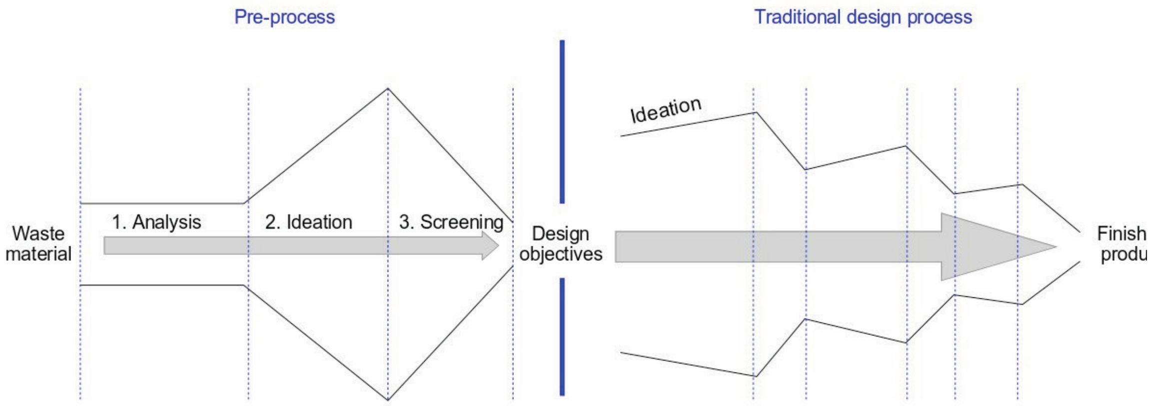

Figure 1. Diagram of the proposed process for designing with waste

The project contemplates three joint sessions with all the people involved for each semester the project runs. In a first Kick-off seminar, the project is introduced in detail and the different students meet each other and the people involved in the project from Semcon, Stena and Chalmers. Later, a mid term seminar and a final seminar are arranged for the students to present their work to the entire W2D group, allowing for fruitful and cross-disciplinary discussion.

Initially the W2D project was thought as a framework for Industrial Design Engineering (IDE) students to develop their master thesis. However, the call for thesis was promoted through the department's webpage, resulting in other students also showing interest to participate in the project. Despite that this was unexpected, the project accepted students with slightly different backgrounds: a couple of students from IDE, a couple of students from the Product Development (PD) masters and two pairs of bachelor students from the Design Engineering (DE) program. All students worked in pairs on their theses, so from the eight students involved, the project obtained four theses (two masters and two bachelors).

3 METHODS FOR DATA COLLECTION

To see how the students solved the challenges of the project, the authors were assigned as supervisors and/or examiners for the different theses. This allowed the authors to follow the process closely

through the **supervision session**, while not interfering with the students liberty to try methods on their own, since non of the authors had had any experience designing with waste previously.
Students were expected to deliver **weekly logs** about their progress. There was no template or structure for the logging, just that one to two pages should be submitted on Friday every week. This was done in order to have information about their progress and problems on a regular basis. After the students' work was finished, these logs were coded and summarized.
Students were addressed in **semi-structured interviews** after having finished their theses. This was done in order to get their personal reflection over their own process. They were asked to visualize their work process retrospectively using pre-prepared phase-markers for the different design stages (i.e. research, evaluation, creation). They could use as many as they wanted and were allowed to add extra information by using post-it notes.
All final **reports** were published via the Chalmers university library system, both in printed and digital format and are now publicly available through the library [12]–[15].

4 RESULTS

All theses done under the W2D framework resulted in projects that were approved at the end of the semester. Table 1 gives an overview of the projects done under the first year, while Figures 2 to 5 are images of the products proposed.

Table 1. Project overview

Student group	**A**	**B**	**C**	**D**
Academic Level	Masters		Bachelors	
Program	IDE[1]	PD[2]	DE[3]	DE
Material used	PVC cable sleeving	PUR foam	Divinycell[4]	PVC cable sleeving
Type of waste	Post consumer	Industrial waste	Industrial waste	Post consumer
Proposed product	Modular sound absorber	4 concepts: Screen walls, cooling bags, lamps, play blocks	Vertical garden structures	Modular outdoor flooring
Development stage	Detailed concept	Initial concept	Initial concept	Detailed product
Main focus	Workshop methodology	Mapping PUR waste flows	Material properties	Product development
1: Industrial Design Engineering. 2: Product Development. 3: Design Engineering. 4: Commercial name for a polymeric foam composed of a mix of polyuren and PVC.				

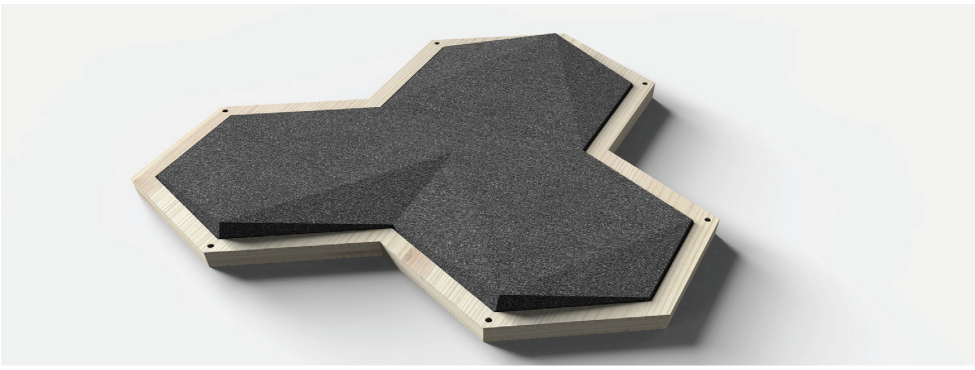

Figure 2. Rekustik, modular sound absorber, of PVC cable sleeving, proposed by group A

All students struggled with the lack of reliable information on the material, specifically concerning the properties and the potential production processes that could be used on the material in the form it was discarded. The four groups generated a large number of possible application ideas, which they later screened or categorized in different ways. All students, except group B, focused on one single application idea in the end that they developed further.

Figure 3. Four concepts for using rebounded PUR foam proposed by group B. Clockwise: Large soft playing modules, lamp, cooling bags and screen walls

Group B preferred to map possible application areas, exemplifying four of them with concept ideas that they had developed. The main results from group B were compiled and presented in a poster that maps the waste flows of polyurethane (PUR) foam. It shows the current recycling methods giving more detail to one of them (i.e. rebonded PUR foam), for which they mapped possible application areas that take advantage of specific material properties present in the recycled material. It can be said that they produced their work, in order to provide other designers with valuable information for using this material for future product development. Therefore, much time was spent on summarizing the material knowledge they gained into a simple, easy to understand format, which led to a convincing result.

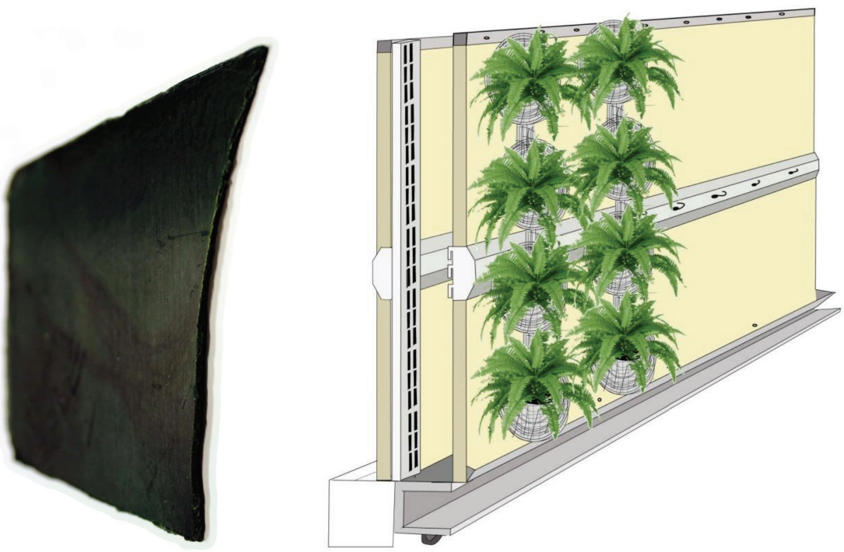

Figure 4. Vertical garden structures proposed by group C. Left to right: Image of pressed Divinycell sawdust board, vertical garden diagram

For the groups that chose one product to take further, there was a "product selection stage" (as named by a student in the interview) that followed the idea generation. This was regarded as the most important phase of the work, spending several hours defining how to best make the right choice. Two groups reported that they spend much more time thinking of how to filter out ideas than actually filtering them out. They found it hard to find good arguments based on concrete facts about the materials' properties and production possibilities to support their decisions. At this stage they opted for using application areas that would not be problematic in any way and production techniques that they were familiar with, rather than proposing something that later would turn out to be unfeasible. Two groups consulted with material experts during this phase to make an informed decision.

All groups contacted material experts during their project. One group commented during the interview that they had expected to be able to ask a material expert all they needed to know about the material, so they could move straight on to product development work. However, they were unsatisfied with the answers they received, so they were forced to investigate the material further by themselves. In the end, the students found researching about the material mostly disorienting, especially given the fact that they often came up with contradictory information, forcing them to carefully examine their sources. Groups A, B and C contacted the experts mostly during the first half of the project (i.e. before the mid-term seminar), while they were focused on learning more about the waste material and its properties. Group D, also focused to learn most about the material in the first half of the project, but mainly building up on the material received from group A and their own literature study. As opposed to the other groups, group D contacted material experts mostly during the final stages of their work, in order to check with them the feasibility of the ideas they had developed, rather than to learn about the material.

5 CONCLUSIONS

The first year's work suggests that in order to support designing with waste, design education would benefit from preparing students for extensive multidisciplinary collaboration. This is needed since significant material knowledge is required, as well as good insight to the selected field of application (that can range widely).

The main barrier for developing products with current voluminous waste flows has shown to be the lack of reliable information about the discarded materials' properties. By the W2D students, this deficiency was experienced as the most challenging stage of the project. Material information is lacking because the producers of the discards are not involved in handling it and because the material properties may change significantly depending on the conditions it was used in. There is a definite need for material research to focus on discard flows as well as engineering virgin materials. Fortunately there is some research done in this line, and for the next semester of the project, students will be invited to work on a specific material that has already been studied and characterized in an ongoing PhD work at Chalmers University (i.e. mixed plastics obtained from electronic waste processing). Since the lack of material knowledge was reported to be so problematic for the first batch of students, for the next semester the authors will test a multidisciplinary student team, embracing one student with a product development background and one student from material engineering to complete the industrial design engineering knowledge.

Figure 5. Återgångeng, modular outdoor flooring for events proposed by group D

When trying to use waste material for new product development, all groups generated several ideas for possible application areas. This process was easy for the design students, who are used to applying methods that facilitate creativity and innovation. All students screened the ideas they generated in some way, during a product selection phase (new to the traditional design process). However, the study shows that good material knowledge is needed at this stage to help designers choose the best options for development.

Unfortunately, the material information that is lacking is not only needed to decide what to make out of the discards. It is also required to know how each material would perform in different application areas. Since this would be very difficult to evaluate for all possible application areas, it is suggested that some sort of material performance testing should be done after completing the product selection phase. Once a prototype with the material has been built, it should undergo the most relevant tests for the application it has been designed for. For example, in the case of the outdoor event flooring made of recycled PVC cable sleeving, a prototype should be exposed to UV radiation and undergo leakage and off gassing tests, to ensure that the use of that product would not emit unwanted chemical to the environment. Normally, this is not done in common product development, because manufacturers rely on their material providers' capacity of ensuring a given performance during a determined use phase. In the W2D case however, the material is obtained by the recycling industry, that cannot guarantee material quality standards.

REFERENCES

[1] European Commission, "Roadmap To A Resource Efficient Europe," Brussels, 2011.

[2] E. M. Foundation, "Towards the Circular Economy: Economic and business rationale for an accelerated transition," 2012.

[3] W. McDonough and M. Braungart, *Cradle to Cradle: Remaking the Way We Make Things*. Farrar, Straus and Giroux, 2002.

[4] Ricoh Group, "Ricoh Group Sustainability Report," 2012.

[5] Wilkhahn office furniture, "After sales - service agreement - Repair - General overhaul." [Online]. Available: http://www.wilkhahn.de/en/service/after-sales/. [Accessed: 28-May-2014].

[6] Basel Convention, "Vital waste graphics 3," 2012.

[7] "Mistra Closing the Loop." [Online]. Available: http://www.closingtheloop.se/sv/projekt/Sidor/default.aspx.

[8] I. Ordoñez and U. Rahe, "How Design relates to Waste : A Categorization of Concrete Examples," in *17th International Conference Sustainable Innovation 2012, 29 – 30 October, Alanus University, Bonn*, 2012.

[9] I. Ordoñez, O. Rexfelt, and U. Rahe, "FROM INDUSTRIAL WASTE TO PRODUCT DESIGN," in *Incorporating Disciplinary Dynamics Into Design Education*, 2012, pp. 65–77.

[10] P. Laseau, *Graphic thinking for architects and designers*. Van Nostrand Reinhold, 1980.

[11] S. Pugh, *Total design: integrated methods for successful product engineering*. Addison-Wesley Pub. Co., 1991.

[12] J. Kääpä and L. Li, "Sound Waste: From Industrial Waste to Sound Absorption," Chalmers University of Technology, 2013.

[13] K. Niskanen and S. Wallsten, "Turning Waste into Product Design: Rethinking Polyurethane Foam Waste as a Resource," Chalmers University of Technology, 2013.

[14] K. Balkhammar and M. Parsland, "Konceptframtagning av produkt gjord av produktionsspill," Chalmers University of Technology, 2013.

[15] E. Brorson and S. Rutgersson, "Gångbar PVC: Att se avfall som en resurs," Chalmers University of Technology, 2013.