

Integration of sustainability in regular courses: experiences in industrial design engineering

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Abstract

The integration of sustainability issues into a regular industrial design engineering product innovation course is a challenge. Simply requiring that student's assignments show sustainable product concepts that are also sound from a traditional business perspective is neither motivating nor realistic. Experiences at Delft University of Technology show that in course development, one of the most important aspects is credibility in written (supervision) and spoken form (business case description, course format). Additionally, putting sustainability in a wider scope, to include social issues like safety, is likely to build enthusiasm with both students and staff without sustainability backgrounds, and is likely to result in better learning processes and assignments, with a higher credibility and more acceptance.

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1. Introduction

The discussion on how to integrate sustainability into higher education is receiving an increasing amount of attention. Two conferences on Engineering Education in Sustainable Development, in 2002 and 2004, have focused on integrating sustainability in engineering education in particular, thereby beginning to develop a body of knowledge and experience. However, this body mainly reports on experiences with teaching separate courses devoted to sustainability topics.

According to Fletcher and Dewberry, two extremes exist of implementing sustainability into curricula of design schools [1]. At one end is a design context, where sustainability is understood within the frame of reference of current design

activities and priorities, i.e. conceiving of and producing economic goods for competitive markets. At the other end of the spectrum is a sustainability context. Here, design is viewed as a dimension of sustainability, rather than sustainability being viewed as a dimension of design as at the other extreme. Here, it draws on sets of backgrounds, expectations, priorities and outputs in accordance with the goals of sustainability (see Fig. 1).

Literature on how to accomplish true integration, not only in course curricula but also in existing individual courses, is quite limited. Some incidental visionary articles on this topic can be identified, such as by Ashford [2], who discussed how sustainability teaching in design and engineering should become trans-disciplinary teaching rather than multi-disciplinary teaching; as well as how it could benefit in helping to open up the problem space of the engineer.

Peet et al. [3] reported on both successful and unsuccessful ways to integrate sustainability into regular engineering courses such as design courses, materials courses or processing technology courses. In Wheeler et al. [4], these efforts

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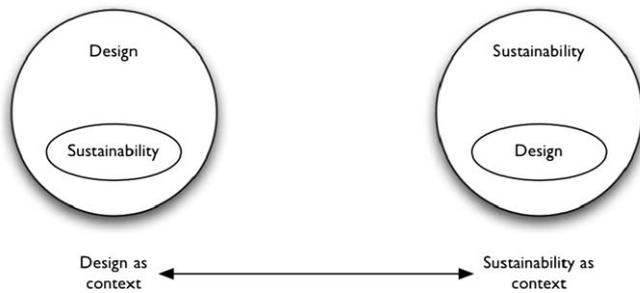


Fig. 1. Range of possible starting points for education in design for sustainability [1].

as well as other courses addressing sustainability in a business context have been acknowledged; however, true hands-on experiences on how to integrate sustainability into a single existing course, in which it has ‘literally’ to compete for time and attention with traditional subjects within that course, and where sustainability is not the main premise on which the course is built, is hardly ever reported.

This article reports on such experiences, focusing on one particular course in Delft University of Technology’s (DUT) Industrial Design Engineering (IDE) Bachelor curriculum.

Through this curriculum, students are educated to become designers capable of designing products and services on a global level integrating a broad spectrum of disciplines as aesthetics, ergonomics, manufacturability, market considerations and sustainability [5]. The complexity of design problems in terms of the number and the variety of issues that are relevant to them means that design is intrinsically knowledge rich and intensive. Not only must relevant issues be identified but also the knowledge required to address those issues must be known, available to and used by the designer [9].

In order to become successful future designers, they need to have to their disposal both domain-specific knowledge and general (domain-independent) procedural knowledge of the design process itself [10]. Domain-specific knowledge can be split up into basic knowledge (academic knowledge of the disciplines relevant for industrial design engineering) and design knowledge (related to problem solving). Integration of various domain-specific basic knowledge disciplines (such as sustainability), domain-specific design knowledge and general domain-independent process knowledge is therefore a key element and goal of design courses [6] (see Fig. 2).

The staff of the IDE’s Design for Sustainability (Dfs) department is responsible for providing students and teaching staff from other departments with domain-specific knowledge and understanding about how to integrate sustainability issues into regular product development processes [7,8]. Generally, this was mostly a unidirectional process as staff members and course coordinators responsible for mainstream courses are unlikely to take any initiative to increase attention for sustainability issues in their courses. Although some passive awareness and preparedness is present with these staff members to address environmental issues, the general attitude is

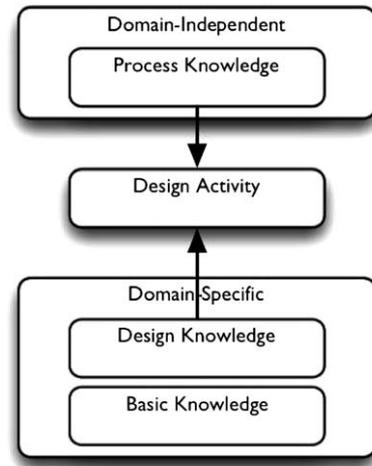


Fig. 2. The three design knowledge components of Industrial Design Engineering Education [6,10].

- ‘As long as it does not affect what students really have to learn’;
- ‘But not at the cost of my course’;
- ‘As long as I do not have to spend time myself to learn about environmental issues’.

All of these responses are perfectly understandable, but they also create barriers for integrating sustainability issues into regular courses.

The DUT-IDE course named ‘Design 5’ is exemplary for a regular product development course, which was offered for many years by the department of Product Innovation Management (PIM). In 1992 the department Design for Sustainability (then called Environmental Product Development) was founded within the department of PIM. As a joint collaborative initiative by both groups, the Design 5 course was singled out by the curriculum developers to be developed into a design course with an increased emphasis on sustainability and innovation. Since then, several years of experience in integrating sustainability into this course have been gained: this experience has yielded mixed sentiments about the success of this process. It is therefore a good candidate for investigation upon the conditions for success, as well as which failure factors play a role in stimulating students as well as staff members to successfully address the sustainability context of product development.

Consequently, this article is designed to contribute to the knowledge and experience on how integration of sustainability issues in regular product development courses can be accomplished. The objective is to provide a useful overview for any teacher and/or curriculum developer wishing to integrate sustainability into regular industrial design or design engineering courses.

2. Background

In the first two years of the curriculum, students in DUT-IDE’s bachelor’s course take courses that address various

topics related to the above-mentioned domain-specific basic and design knowledge. With respect to sustainability, students are required to take the course cluster Design Engineering and Sustainability, which includes a basic environmental sciences course. In this course, students obtain knowledge about environmental impacts related to products and their environment, and about tools for integrating such knowledge in product development processes. The content of this course is to a large extent based upon the Ecodesign methodology and tools as provided by the UNEP manual 'Ecodesign: a promising approach to sustainable production and consumption' [11].

In the second semester of the last year of the bachelor's curriculum, the focus is on the integration of abilities, including, as such, the integration of sustainability issues into product design. The main course that addresses the latter is the so-called Design 5 course. In this course, that addresses most of the Product Development Process (PDP) chain (from mission statement to conceptualisation), students are required to explicitly address sustainability issues, while at the same time taking traditional business considerations into account, as well.

The Design 5 course is one of three elements of the 16 ECTS (European Credit Transfer System) study points course cluster that further consists of two theory-based courses, which are 'Product Development in Industrial Context' and 'Market and Consumer'. The objective is to encourage students to apply the theory obtained from these latter courses into the Design 5 course.

The arrangement of the Design 5 course is as follows. Teams of five students each are simulated to operate as 'young, innovative design companies', and to profile themselves as such through the use of logos, presentation templates, etc. Based on a business case description, which they receive in the first week, students advance through a number of stages that represent, in an extremely compressed time frame, the complete product development process (see Table 1). After each stage, which usually takes one week, they report to an (impersonator of a) company representative referred to as 'the client'.

Selected business cases are usually based upon SMEs with little or no prior experience with sustainability issues. The businesses are real-life companies; the business case descriptions are however, partly fictitious and are often adapted from earlier years where these cases have functioned as cases for the Design 6 course, which is part of the Master's curriculum and which entails interaction with a real-life company.

Because of the little experience that these SMEs have with sustainability issues, the sustainability aspect is usually (partly) artificially integrated into the case descriptions and assignments.

Apart from interaction with the 'client', the student teams also receive supervision from a staff member acting as 'coach'. The role of the coach is to stimulate student teams, see to it that they remain on the right track and to act as a sounding board for positive as well as negative feedback. Typically, the coach takes a supportive and facilitative attitude whereas the client is expected to be much more critical, sometimes even in unexpected ways; for example, he or she can

Table 1
Subsequent course stages in the IDE Design 5 exercise

Stage	Deliverable
Meeting 1: Pitch	A long-term vision on the company's product line and product environment First ideas about possible future product lines Identity, mission, approach of the design team
Meeting 2: Internal and external analysis	Assessment of current position of the company Strengths, Weaknesses, Opportunities, Threats Strategic innovation directions
Meeting 3: Product development assignment	Market segmentation, consumer needs List of product requirements, criteria First ideas for conceptual design
Meeting 4: Conceptual design	Selection of a few ideas with high potential Justification and underpinning of final concept choice
Meeting 5: Sketch design	Presentable sketch design Information about potential price, market potential, necessary investments, environmental assessment
Meeting 6: Business plan	Detailed design, with necessary technical detail Financial risk assessment Market introduction and positioning Proposal for further product development activities

pretend to have a sudden change of preferences, as long as this would support the envisaged learning of the course.

A client typically serves eight teams of five students, while coaches supervise four teams. The approximately 15 staff members (clients and coaches) that supervise this course in general, have no professional background in sustainability issues, except for two members who are responsible for the integration of sustainability issues into the course, and who are designated as environmental specialists, to be consulted by students during the course (in addition to their roles as coaches).

Each course is concluded with students writing an individual reflection called 'learning experience' [12], which is a required part of the course, and which is not only a valuable learning experience for them, but it also provides a valuable information source for staff members for making adjustments to the course offerings, whenever that is necessary.

A second source of feedback is provided by students filling in standard evaluation forms that are used for evaluation of all courses offered in the Industrial Design Engineering curricula. Within these forms, apart from standard questions that apply to all courses offered, there is also room for questions customised for individual courses. In the evaluation of the 2003 course, 76 completed questionnaires were returned.

3. Learning experiences until 2003

3.1. General learning experiences

In general, the Design 5 course received a positive evaluation. The evaluation of the 2003 course shows that students judge either positive or very positive about issues like the connection with the rest of curriculum (76%), the relevance of the course (97%), the grading system (78%), and the organisation of the course (62%). Including the neutral makes a total positive score of higher than 90% without exception. From the individual reflections it is also clear that, almost without exemption, the students very well received the course. Putting theory into practice, to experience making something out of nothing, teamwork and the opportunity to choose your own work pace and methods are among the main reasons for that. This is perhaps best illustrated by a number of quotes (translated from Dutch) from the reflections:

“I would like to state that I very much like the way this assignment is set up. It is independent, but if you need help it is possible to get it, and also when you are derailed there is a back-up. But in general, what comes out, comes out of the students themselves and I think that is a great starting point”.

“In general I think Design 5 is very a great educational experience. For the first time in my Industrial Design Engineering career I have the feeling that I have a reasonable kind of base level”.

On the critical side, students appear to have trouble with coping with incomplete information:

“I think that the project could have been more educational if we had received clearer instructions on how to make financial and environmental analyses. I do not consider guessing and estimating figures a sensible learning experience, although I realise this will happen in real life more often than I think, I guess”.

“What was disappointing was the financial part of the assignment. I don’t have a clue how much a marketing campaign or contracting out a part of a process costs. And we learn for example how to make up a balance sheet, but not where to get the figures from”.

“When beginning my Industrial Design Engineering studies I really thought that when I would be finished I would know everything. That was the most frustrating part when starting Design 1, that you know so little and that you don’t have a clue how you ever would find out about things. But gradually you learn that there will always be things you don’t know about, but you learn to deal with that. You learn how to make realistic estimates, or a justified guesstimate. I think that is the most important thing I learned from Design 5”.

Remarks like these are fed back to the staff responsible for these subjects.

3.2. Learning experiences related to the integration of sustainability issues

The process of integrating sustainability issues into the Design 5 course has, over the past years been a learning process for staff members, and not without problems; in fact, the prevailing opinion of staff and students has usually been that the resulting proposals for innovation ending up in the final reports have only a limited sustainability content. From the 2003 feedback questionnaires, it was learned that a minority (26%) stated that they had truly learned how to integrate sustainability in product development. Moreover, 43% stated that they did not or did not at all consider the plenary sustainability instructions as being useful. In their reflections for these years, students had indicated that they found it hard to include sustainability issues because of two reasons: they did not know how to, but mainly because they felt there was little incentive to do so. In itself, the perception of the latter reason was stimulated by the lack of stress given to sustainability by clients and coaches, but explicitly also by the lack of evidence that in the real world a sustainable innovation would be in demand or could even survive.

With respect to the lack of knowledge, in earlier years it was already decided to organise several brushing-up classes during the course of the Design 5 assignment, to repeat information provided in the second year and to stimulate creativity; in itself a kind gesture to the students, partly in response to disappointing reflective comments like:

“The staff assumes that we still remember a lot from the environmental sciences course, even when we took it already one year ago!”

Although the ‘complaint’ that the course is offered one-and-a-half years before the Design 5 course, can never be an excuse for not remembering its contents; it was found that the organisation of the second year elementary environmental science course was not very well aligned with the organisation of the Design 5 course. First of all, lectures in the second year course receive relatively low attendance; it is very well possible to pass the course by doing assignments without attending the explanatory lectures. However, the explanatory lectures are probably more stimulating for addressing environmental issues in a product development project than the, rather technical, assignments. In other words, the elementary environmental science course was probably too technical and LCA-oriented, and did not sufficiently address practical issues in a ‘real life’ business context. Within the bachelor’s curriculum revision currently taking place at DUT-IDE, it is envisioned to transform the ‘environmental sciences course’ into a ‘sustainable product innovation’ course in order to create a better connection between the two sustainability related courses within the curriculum.

The reported lack of incentive however, was taken more seriously as an indication that a thorough re-evaluation of the way the course is set up and supervised was in order. In the following section it is reported how this re-evaluation has provided new insights on how to offer this course in years to come.

4. Results re-evaluation

The re-evaluation has shown that five main elements appear to be crucial in order to facilitate the improved integration of sustainability issues in regular business cases. These are related to: (1) Course format; (2) Definitions; (3) Business case descriptions; (4) Client support; (5) Coach support; (6) Sustainability expert support.

In the following paragraphs, each element is addressed.

4.1. Course format

The course format is defined, in this context, as the way the course is set up in terms of organisation and procedures, but excluding issues of a content nature. Evidently, in order to stimulate students to integrate sustainability considerations into their assignments, the support provided through the course format is very important. Without such support, the credibility of the importance of integrating sustainability is simply not there. Staff members pressing for more attention for sustainability issues are only taken seriously when the course format is supporting them. Of course this works both ways; staff members (especially those with other than sustainability research backgrounds) are more likely to stress the importance of sustainability when reminded and supported by the course format.

The re-evaluation of the course revealed a number of possibilities to adjust the course format in a way to ensure more credibility regarding the urgency of addressing sustainability issues. One category of options was to pretend the company had the opportunity to participate in an ecodesign competition, or had the opportunity to obtain a subsidy in case they would engage in a sustainable innovation. The risk of such course formats interfering with other learning goals (which include also all financial aspects of regular product development) was considered to be too high however. Another option was to replace the company representative with the representative of, for example, a 'green' investment bank. In fact, this option was carried out by one client. This person was pretending to be the indirect spokesperson for a tent manufacturing company that suffered financial problems and that would get a loan from this bank only in case of a sound plan for sustainable product innovation. Clearly, here the drawback of less attention for financial issues was not present, and in fact the system, was considered quite positive. However, the results of the students in this case were relatively bad in comparison to other groups, which could be incidental or due the specific case; in the end it was decided to leave such stage settings up to individual coach/client duos.

4.2. Definitions

It became clear that the perception of what sustainability is all about was unclear for students as well as staff members involved in the course. Although definitions and explanations were given at the beginning of the course via plenary classes and staff preparation workshops, apparently, during the course

many people reverted to using and relying on their own definitions and perceptions of sustainability; these were mostly more strict than intended. This resulted in students as well as staff members solely addressing aspects such as environmental impact reduction of materials, lifetime extension of products or recycling issues, rather than using broader notions of what sustainability is generally understood to be in the environmental sciences research community.

This notion led to the decision to pay much more attention to the communication of what sustainability can be understood to be. In all types of communication (workshops, classes, internet, meetings, case description) it was made clear that sustainability was supposed to be more than just purely environmental issues, and should in general refer to 'beneficial to society'. This was explicitly to address social issues as well, in particular including safety issues. This latter option, by some regarded as a safety net because safety is not regarded by them as a 'true' sustainability item, was for example eagerly used by students when their assignment was to develop an innovative, sustainable product concept for short to medium term for a €50 million company focusing on safety and lighting accessories for houses and bicycles. Figs. 3 and 4 illustrate examples of final designs of the typical Design 5 assignments.

4.3. Business case descriptions

The re-evaluation also made clear that the business case descriptions, in most cases, lacked a level of credibility; from the text, students in general were not convinced nor motivated to address sustainability the way the staff, and especially the sustainability specialists, would like them to have done. Specifically, a discrepancy was perceived between written (in the case) and spoken (by the client) motivations to engage in sustainable innovation. It was decided that the following improvements to the case descriptions would likely improve this situation:

- There should be a mission statement or company goals related to sustainability issues. This should be done with care, as casual, mindless mentioning of sustainability without attention to the issues addressed below is likely to be counterproductive.
- The environmental goals of the company should not only be stated as such, but should be integrated with the company's other goals. For example, a paragraph such as:

'The new product concept should target a 5% increase in turnover, and in a worst case scenario result in a minimum net profit of €50,000. It should also be a good product from the sustainability perspective'.

Should be replaced with:

'The new product concept should target a 5% increase in turnover, and in a worst case scenario result in a minimum net profit of €50,000. It should be analysed in what way

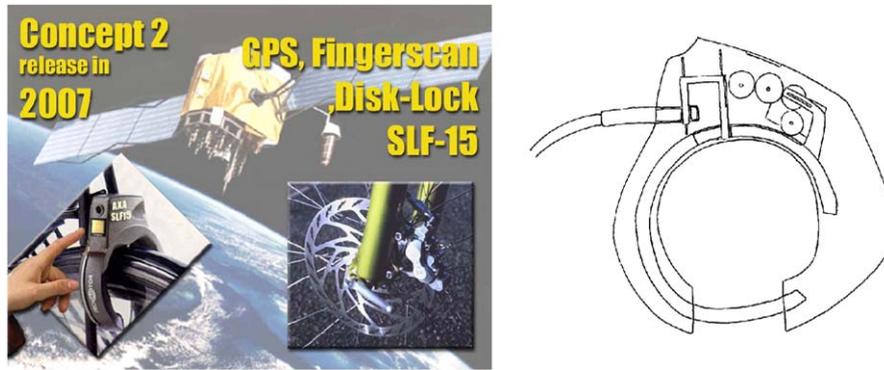


Fig. 3. Concept and drawing for a finger-scan bicycle lock developed by Design 5 students.

sustainable innovations could contribute to these goals, and whenever opportunities to do so are present, priority should be given to such innovations’.

When stating sustainability goals, it is wise to distinguish between long-term and short-term goals. Even when a case provides difficulties for students to develop financially sound short-term sustainable innovations, they can be asked for long-term vision in terms of sustainability. However, stating *only* long-term company goals is likely to result in a bad match with the actual product development assignment. Therefore, attention should be paid to balancing short and long-term goals.

- The background information in the case descriptions should preferably offer more company-specific information related to sustainability to increase credibility for students. It is even better to state that the company has no prior experience with sustainability issues than to state nothing at all.
- In the situation where case descriptions are prepared by staff members without environmental background, it is wise to have these cases read by staff members with an environmental expertise to check for the above issues.

4.4. Client support

The role of the client is instrumental in both stimulating and inspiring students. This applies for all aspects of the course, and in particular, for sustainability issues. Without the client explicitly asking for sustainable options as well as the criteria on which they should be evaluated, the experience is that relatively little will happen. The re-evaluation showed that some clients are afraid to repeatedly ask for sustainable product concepts or even product improvements because they either do not believe that such improvements are possible, or they are afraid to do so because they fear that it will take away the attention of what they consider the more important learning goals of the course.

This is why, in the past course year, extra efforts were made to make clear to the staff what the role of sustainability issues in a course like this could or even should be. The main train of thought that was communicated is the following: it is possible to let students think about and consider sustainable aspects of product development without requiring them to actually make a conceptual or detailed design for a sustainable product. A good way to do this is to clarify that the product development process roughly consists of (i) searching for and finding options, (ii) evaluating them by appropriate criteria, and

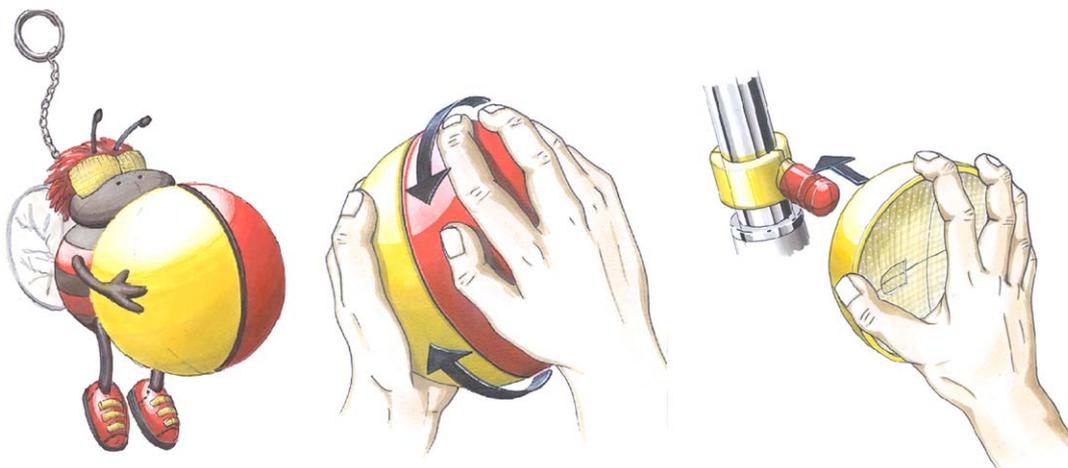


Fig. 4. Concepts for children's bicycle lighting developed by Design 5 students.

(iii) ranking them in order to select the most promising options for implementation. Sustainable product development would then involve an additional source for creativity to search for and find options, as well as a source of additional criteria on the basis of which options are evaluated. Such criteria would include not only short and/or long-term reduction of environmental impact in comparison with alternative concepts, but could also include a number of criteria in a wider sustainability context. Such criteria could be generally applicable, such as responsible manufacturing (e.g. child labour, responsible forest maintenance), or reflect a specific context for the company under investigation (such as subsidy requirements, or specific stakeholder interests). The subsequent ranking and selection could then yield an option originating from a sustainability perspective, but this would not necessarily be the case. So even when this process results in a product concept that apparently has no contribution to sustainability, it would be clear that the students had taken the issue into consideration but dismissed it as not making good sense from a business perspective. Being made aware of this train of thought, clients were also made aware that they could play an important role in the 'level of sustainability' in the final product concept, by putting relatively high weight factors to sustainability criteria – but they would be free to do so. It was expected that awareness about this methodology would take away, at least, some of the general dissatisfaction, expressed as 'there is so little sustainability visible in the final product concepts that students developed'.

The above process would likely be facilitated by clients regularly asking questions like:

- “I am trying to get a feel for what sustainability could mean for our company...”
- “Can you tell me what is happening out there concerning this type of issue?”
- “Colleagues from other companies tell me that sustainability works for them, it even results in cost savings, do you think that would work for us too?”
- “What do we have to gain with it? What do I risk losing?”
- “How do your plans fit in your long-term planning?”
- “Does this yield or affect the envisaged short-term goals?”

Finally, the recommendation was made that clients should approach sustainability questions with an appropriate amount of scepticism, and that they should be aware of or be able to refer to some factual material to underpin their claims and to answer simple student questions, like “what are your experiences with environmental issues in your company” or “did you do any marketing studies in this field”. With respect to the latter, an honest “no, but maybe you can find out for me” was recommended as an answer and preferred over “I think our customers do not care” or “no doubt some do care”.

4.5. Coach support

In the current arrangement of the Design 5 course, coaches have a background role; in principle it is up to the students to

request their feedback. However, coaches will, in most cases, proactively approach student teams as well, asking for an overview of their activities, proactively looking for wrong turns in the process and anticipating problems of both organisational and content nature.

4.6. Sustainability expert support

As far as the sustainability element of the course was concerned, two sustainability specialists were available for consulting by the students during the course, to cover those sustainability issues that most coaches are not familiar with. Their main role was to provide methodological support for sustainability issues, and to stimulate creativity when looking for 'sustainable ideas'. This process was done through plenary classes, designated afternoons for consultancy, and on an ad-hoc meeting basis. Referring back to the options and criteria discussed under the header client support above, it was pointed out in what directions options could be found (such as integration of new technology, searching for opportunities for cooperation in the supply and distribution chains, better focus on transport and distribution, opportunities for product-service systems, new materials) and what kind of (additional) criteria could play a role (such as reduction of environmental impacts, contributions to image, creating business value, legal compliance, finding/expanding markets).

5. Conclusions

As explained above, the main concern in the previous years of the course was to take away the general dissatisfaction of the level of sustainability elements in the final assignments of the students, and to that end the teaching staff implemented changes in the course that were implemented in the 2004 spring course. One of the main goals was to highlight that it should be considered a satisfactory result when:

1. Students have identified options for sustainable product concepts,
2. Students have evaluated them, as well as all other options for product concepts, also on the basis of sustainability criteria.

This should be considered a satisfactory result even when the final proposal for a new product concept is not stimulated by sustainability concerns.

It is difficult to determine to what extent this 'new' approach has been successful, since insights into the exact decision-making processes of students are not available. What has been noted, however, is that less dissatisfaction was expressed about the sustainability content in the students' assignments. The percentage of students that stated that they had truly learned to integrate sustainability into product development went up from 26% in 2003 to 48% in 2004, which confirmed that attention for the six items previously described in this paper had at least partially paid off. Since apparently, there is little change in the number of final product concepts stimulated

by sustainability issues in comparison to earlier years, further reason for improved satisfaction must be in the fact that a number of perspectives, like the safety perspective, are now more accepted as forms of sustainable product development. Results still depend on the attitudes that clients and coaches display towards sustainability issues. Some clients, as well as coaches, persist in asking for numerical proof (in terms of LCA assessments) even though they do not ask for or know that without a frame of reference, such proof would be meaningless. Furthermore, in 2004 56% stated that they did not or did not at all consider the plenary sustainability instructions as useful, which was up from 43% in 2003. Opinions collected from the reflections provide a reason for this: students would like to have more case-specific input and discussion on sustainability issues, and they found it difficult to apply generic insights in sustainable product development in specific cases. From this, it was concluded that from 2005, plenary sessions for sustainability instructions would be replaced by a system where teams of students have obligatory meetings with sustainability experts twice during the course, in order to discuss sustainability issues on a case-specific level.

In one of the individual reflections, a student stated:

“I think that when you really want to do it right, sustainability should be the only starting-point in this project”.

The staff members responsible for the Design 5 course explicitly do not agree with this statement. The learning goals of this course are to integrate all relevant aspects of product design, each with appropriate weight. In most cases it is up to the students, in dialogue with their clients, to determine what aspects should receive more or less attention in a particular business case study. It is however, clear that when not specifically asked to integrate sustainability issues, students have no incentive to proceed with them, not only because most staff members (clients and coaches) have little experience to do so, but also because it is a business reality that sustainability usually plays a minor, though increasing, role in most industries.

Putting sustainability in a wider scope, to include for example issues around consumer safety, has helped to make staff members better accept sustainability as a source for creativity and evaluation. In that respect and referring back to Ashford [1], more than just glimpses of trans-disciplinarity are becoming clear in Design 5; sustainability certainly brings elements to product development that traditional subjects did not bring.

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