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A Design-Engineering Interdisciplinary and German-Korean Intercultural Design Project Course

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Abstract
The paper presents a project-based design course that provides students, majoring in Industrial Design or Engineering Design and residing in Korea or Germany, with opportunities to learn how to effectively collaborate in an interdisciplinary and intercultural team. This course was developed in order to address the ever-increasing needs for designers and engineers to be equipped with such capability in collaborative product development. Based on the observations made during the design projects, many issues have been found. Important issues include conflicts due to different value priorities and different design processes between design and engineering students, and different ways of thinking between Korean and German students. The paper also illustrates how these issues are resolved or alleviated in this course. In conclusion, several suggestions are made for successful education for interdisciplinary and intercultural design collaboration, which are hoped to be beneficial to those planning similar courses.

Keywords: Design-engineering collaboration, collaborative design education, intercultural collaboration, team project

1 Introduction

Aesthetic quality of end-user products has been gaining greater importance in the product selling power. This trend has strengthened the importance of industrial design because aesthetics is considered as a role of industrial designers. Yet, it is obvious that aesthetic form design developed by an industrial designer is meaningless, no matter how beautiful it is, unless it is realized by engineering designers and produced by manufacturing engineers. Thus, industrial designers and engineers must closely collaborate with each other to successfully complete this chain of activities – styling, engineering design, and manufacturing.

Though all this is well understood, newly-employed industrial designers and engineers are embarrassed and often overwhelmed when encountering this tough task of collaborating with a totally different type of colleagues, *for the first time*, at their work. This is because they usually have no opportunity to learn at school how the entire process of product development is conducted beyond their own area of study and how to deal with the challenges that may occur due to the potential conflicts with other disciplines. This lack of learning opportunities leads to many problems, sometimes quite detrimental, in almost all product development and manufacturing companies, and thus entails huge amount of wasted time and cost. In light of this, there is a clear and universal need for schools to provide such learning opportunities to future designers and engineers.

Globalization is another mega trend, which is both manifested and accelerated by the multinational operation of many companies. Even if a company does not have branch offices or operations abroad, tasks at different stages of product development are often done in different countries. For example, a product to be sold in Korea may be styled in Korea, engineered in Germany (with computer-aided engineering (CAE) tasks outsourced to India), and produced in China. In this scenario, the designers and engineers on the product development team face an additional challenge: to overcome the intercultural difference. The intercultural challenge ranges from different ways of reasoning to different thinking processes, to different ways of trading off, and to different working styles.

In order to help students cope with these two challenges at their future work, three departments in two countries agreed, in 2007, to develop an interdisciplinary and intercultural course, and have offered the course annually since 2008 up to the current year of 2014 (now for the seventh run). The three departments involved are the Industrial Design (ID) department and the Mechanical & System Design Engineering (MSDE) department of Hongik University in Korea, and the Engineering Design Department (ikt) of RWTH Aachen University in Germany. The literature has a number of papers relating to similar college courses, yet most of them are either intercultural or interdisciplinary [1-3]. There are a few cases of both interdisciplinary and intercultural courses, but they are mostly intercultural between western cultures. So, the case presented in this paper may be quite unique.

The paper first delineates the course in Section 2, and then presents the issues found during the projects in Section 3. Section 4 elaborates and discusses these issues along with the measures taken to address them. Finally, the paper is concluded in Section 6 with suggestions for those who plan to offer similar courses.

2 The course

This section introduces the course in terms of the participating students and instructors, major contents, project themes and execution, and project outcomes.

2.1 Course outline

This course is entitled 'Design-Engineering Collaborative Product Development' at Hongik University, and 'Collaborative Product Development' (CoPro in short) at Aachen University. (It shall be called CoPro hereafter in this paper.) Though there have been minor changes in the seven runs of CoPro, its major structure has remained intact. In each year, a total of thirty students, consisting of ten from each of the three participating departments, have been enrolled. Instructors for this course are the authors of this paper, consisting of one or two from each participating department.

The predominant focus of the course is on the design project that is worked out by student teams that are all equally interdisciplinary and intercultural, i.e. all teams consist of equal numbers of students from the three departments. Lectures are also offered, mostly in order to deliver the knowledge needed for the project at the proper time. CoPro has three class hours per week for fifteen weeks of an entire semester, but students typically spend three to five extra hours per week for their project. Most of the time during the course, lectures are shared and the project is executed online using a commercial video conferencing program, except the mutual ten-day visits during which lectures and project are conducted offline.

2.2 Project and student teams

The theme of the project has varied from year to year, but has always been on developing vehicles or, in general, mobility devices, as listed in Table 1. In the early years (2008, 2009), standard or large vehicles were developed. The theme shifted in 2010 to smaller vehicles such as personal mobility or two-seaters. A direct reason for this shift was that the project theme in that year was given by a sponsor, a spinoff company of a Korean automotive enterprise. Not a direct but more important reason, in light of the purpose of CoPro, is that personal mobility devices such as bicycles and tricycles induce more fierce conflicts between designers and engineers, and thus more close collaboration between them, which is the main purpose of CoPro. This is because the structurally designed frame is externally visible in most cases of such personal mobility, and thus will directly affect the visual impression of the device.

Table 1. Overview of projects

Year	Theme	# Teams	Sponsor
2008	Micro e-vehicles	5	No
2009	Municipal service vehicles	5	No
2010	Electric tricycles	2	Yes
2011	Electric quad-cycles	2	No
2012	Zero-emission personal commuters	5	No
2013	New-material minimal mobility	5	Yes
2014	Safe minimal mobility	5	Yes

Except for 2010 and 2011, the final deliverables expected from the project were digital models, i.e. Alias™ and NX™ models, with a reasonable level of details. In the two years, 2010 and 2011, the final deliverables were expected to include a working prototype along with all detailed digital models. Due to the obviously increased work load, the number of student teams was reduced to two in those two years whereas it was five in the other years. The project in 2010 is mostly discussed in this paper because of far many and diverse issues observed from the closer interactions among students, required by the enormous task to build a working prototype. Though prototype building was planned in 2011 as well, the project did not reach that level, for several reasons including the lack of sponsorship.

2.3 Process of design project

Whereas there is a well-established engineering design process [4, 5], there seems to be no such design process acknowledged by most industrial design professors (unless at a very abstract level). Therefore, students were given the engineering design process, adopted from [4, 5] and modified as shown in Figure 1, at the outset and asked to follow it closely.

The tasks in the recommended design process are divided into two parts: defining the problem (shown on the left of Figure 1) and solving the problem (on the right). In order to define the problem at a proper level of details, each team should research the market and define the target group, and then find the requirements by interviewing or conducting surveys on the target group. The outcome of the problem definition will be engineering requirements that must be fulfilled to satisfy the target group and defeat the competition on the market.

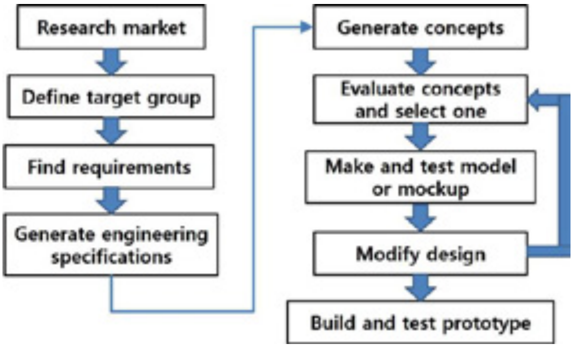

Figure 1. Design process recommended for project

Then, in the solution part, as many concepts as possible that can meet the engineering requirements are generated using various creativity-inducing methods. Once many concepts have been generated, they are quantitatively evaluated and compared with each other using the engineering requirements as the metrics. Based on the comparisons, the best concept is selected. Then, the concept is iteratively tested and improved by conducting computer analyses or experiments and mockup testing (which is mandatory in CoPro). In the case where the selected concept turns out to fail after all, another concept should be picked and go through the same iterative process. Once a concept has passed this stage, then all the improvements are integrated into a complete design, and a working prototype is built (which was done only in 2010 for CoPro) for further tests. Of course, in real companies, the engineering designers will further develop it based on the testing of the working prototype.

As indicated above, industrial design students are not taught of such a process. One of the reasons for this is that many practitioners and even some professors in industrial design seem to believe that following a fixed design process often restrains and hinders creative design. A paper [6], however, presents a contrary view of industrial designers working as a team, who believe that a common process shared among the teammates is crucial for successful design

2.4 Examples of project outcomes

Three major types of project outcomes of CoPro are digital models, soft mockups, and working prototypes. Figure 2 shows examples of digital models generated, which shows design rendering and engineering CAD models, illustrating close collaboration between design and engineering students.

Figure 2. Examples of digital styling and engineering CAD models

Also, Figure 3(left) shows an example soft mockup, which is being checked by a student in terms of the ergonomic aspects of his team's design. The mockup is made of soft materials such as Styrofoam, balsa wood, hard-board paper, PVC pipes, and acrylic plates. An example of working prototype built in 2010 is being test driven in Figure 3(right).

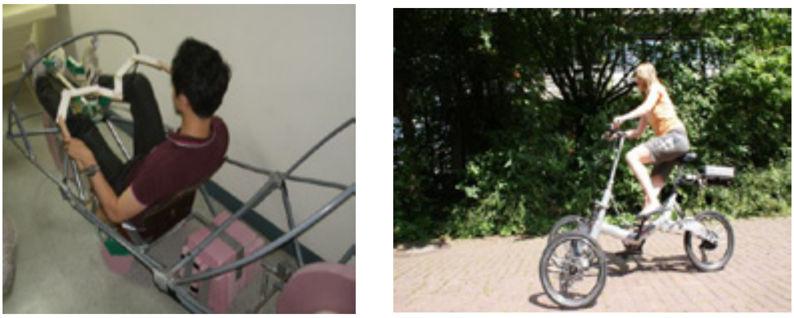

Figure 3. Example of soft mockup and of working prototype

3 Issues found in the project

This section lists major issues that were either expressed by the students or observed by the instructors. All these issues have been found, only in varying degrees of relative importance, in almost all runs of CoPro. This paper uses the data collected in 2010 because a systematic questionnaire and interviews were conducted and analysed in that year.

3.1 Issues mentioned by students

A student survey conducted at the end of the course in 2010 revealed that there had been five major hurdles that had kept the project from running more smoothly and successfully. In the order of the frequency in being mentioned in the student survey, the hurdles found were (1) ineffective communication among students (27%), (2) ineffective project management (22%), (3) different processes between designers and engineers (20%), (4) different value priorities between designers and engineers (13%), (5) ineffective management of digital data (13%), and (6) collaborating minds (5%), as shown in Figure 4.

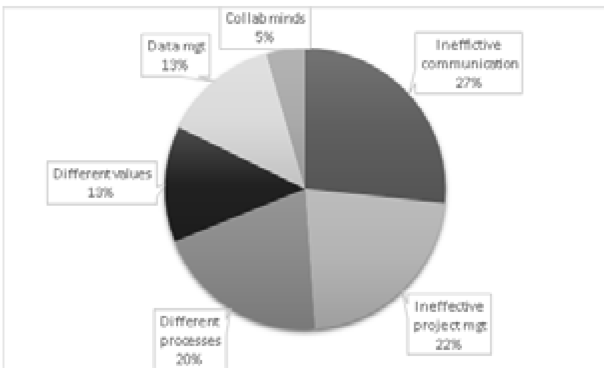

Figure 4. Hurdles mentioned by students in a survey (2010)

Interviews with students were conducted after the survey mainly to clarify what the students meant by their writing in the survey form. The thus clarified issues are briefly explained here though each will be discussed in much greater detail in the next section. Ineffective communication, ranked the first, may be partly attributed to technical defects of the video conferencing program, but mostly to the intercultural difference such as different ways of expressing one's thoughts. The second hurdle, ineffective project management, is mostly about the waste of too much time in defining a target group. The interdisciplinary difference in design process, ranked the third, was mostly mentioned by engineering students, both German and Korean. From their perspective, design students' working process looked like a black box because there was no clearly defined process. The fourth issue found by the students is again of interdisciplinary nature: designers consider beauty and user experience most valuable while engineering students highly value function, safety, and cost. Ineffective management of digital data, ranked the fifth, is about the missed updates of the digital data stored in the product data management system (PDMS).

3.2 Issues observed by instructors

All instructors of CoPro are always alert to problems and issues that may occur during the course. Every time an issue is detected, interviews with students are conducted to find out the nature of the issue, and then a decision is made regarding whether a direct intervention will be made or not. Instructor intervention is made only when the problem is deemed crucial enough to destroy the entire project, or students' attempts to resolve it would not offer meaningful educational opportunity. In all other cases, instructors only monitor what measures are taken by the students and how the issue evolves as a result.

Issues detected by the instructors, in addition to those mentioned by students, include (1) lack of students' skill and domain knowledge, (2) imperfect digital styling data, (3) passive attitude of engineering students in concept generation, and (4) problems unexamined in the CAD model. The first issue is that many students were not well skilled in CAD, CAE or domain knowledge such as basic vehicle dynamics, which delayed the project progress. Imperfect styling data in the second issue above means the incomplete finish of the design students' digital work that causes trouble in engineering CAD work. The third issue of passive attitude of engineering students is that engineering students tend to wait for industrial designers to come up with the overall design concepts, and then start engineering design with it. The final issue listed above is that students cannot find problems in their design until they make and test a mockup, which could have been found by examining their CAD models.

4 Discussion of issues found

The issues listed in the previous section are each discussed closely in this section. The discussion does not only give full description of each issue but also indicates what measures have been taken to resolve it and what lessons have been learned.

4.1 Ineffective communication among students

This issue is mostly of intercultural nature. Korean students tend to be relatively passive in group discussion whereas German students like to make their own points strongly and convince others. Relatively quiet Korean students often raise questions and express objections only at the final moment that a decision is about to be made, which causes delays in decision making.

Another intercultural difference that hindered effective communication is Korean hierarchy associated with age. Age carries much more importance in Korean culture than in German culture. So, the older students in a team tend to have more power than younger students, which makes younger students hesitate to object to the opinions of older students. This of course caused delays and confusions in communication among teammates.

The last, but most profound, intercultural difference observed in CoPro is the different ways of thinking between Germans and Koreans. According to Nisbett [7] and other psychologists, westerners tend to separate an object from the environment and then analyse whereas Asians tend to view and think about the object as it is in the context – a 'holistic' view. Though it is not clear what specific influences this difference has on the CoPro project, it must have contributed, at a profound level, to the conflicts between Germans and Koreans. It is interesting to notice that there is a claim that this difference makes it hard to teach Asian students the functional decomposition approach [8] – an approach to reach a complete solution by combining solutions to sub-functions that comprise the overall function of a product [5].

Most of these problems of intercultural nature are found to have been resolved after the first offline meeting when the German students come to Korea in mid-May. This is due to the 'chemical reaction' that occurs during the offline activities such as eating, drinking, and working together on the project. It proves the importance of face-to-face interaction even in this era of information technology (IT). Once these problems are resolved, the strong teamwork drives the project and climaxes in the second offline meeting period, that is, when Korean students visit Germany towards the end of the course (typically in late June).

4.2 Ineffective project management

The project is usually carried out by roughly following the suggested process shown in Figure 1, in which significant time waste has often occurred with the task of defining the target group. This seems to be mainly due to the lack of knowledge and experience of students in this task. In order to address this issue, a short lecture on market segmentation and value proposition has often been offered in latest years. The problem seems to persist, though a bit alleviated, even with such a training.

Considering the fact that this task is usually done by marketing experts in the real situation, the target group could be defined by instructors. Yet, students are still asked to do this task in order to provide them with an opportunity to learn or at least think about it, which is good for preparing the students for future collaboration with the marketing department as well.

4.3 Different processes between designers and engineers

As explained before, the recommended design process in Figure 1 begins with clearly defining the problem and then proceeds with solving the problem. In this sense, this engineering design process is called the 'problem-oriented' approach. The advantage of this process lies in that the solutions generated are pertinent to the problem because they are all based on a good understanding of the problem, and the one selected is likely to be one of the best because the selection is also based on the requirements of the well-understood problem.

In contrast, most industrial designers work in the so-called 'solution-oriented' approach. This means that industrial designers typically come up with a solution first and then develop the design such that it can meet as many and as much of the requirements of the problem as possible. In this approach, the requirements of the problem are not well known at the outset, and the design evolves as the requirements are developed. As such, the final design may not be claimed to be one of the best in this sense.

This interdisciplinary difference in the design process causes problems in CoPro, particularly in the early stage where industrial design students present their primitive, yet holistic design while engineering students are still analyzing the problem. In most cases, this confusion has been resolved through trade-offs, e.g. industrial design students later develop a totally new design that can be a good solution to the well-defined problem, or engineering students keep providing feedback to the design so that it can be continuously revised to fit the evolving problem definition.

4.4 Different value priorities between designers and engineers

Designers and engineers typically have different value priorities of various aspects of a product. Engineers often believe that the top values of a product are the function, durability, cost, and safety whereas industrial designers tend to put beauty, ergonomics, and usability at the top value priorities. This difference, of course, is one of the main reasons that engineers and designers come to conflict, and also that CoPro was developed and is being offered to the future engineers and designers.

This inherent difference and resulting conflict have been observed in every run of the course. For example, industrial design students in a team proposes an egg-shaped shell to signify safety, then engineering teammates object to this idea based on the difficulty and high cost associated with the manufacturing of such a shape. No faculty intervention is usually made to resolve this issue because leaving students to solve it by themselves better serves the main objectives of the course. In most cases, students find their way out of this problem.

4.5 Ineffective management of digital data

Most companies, particularly those big or global ones, use PDMS to manage the huge amount of working data that evolve as a design project proceeds. CoPro students are taught to use a PDMS and update their data every time they make a change. It is, however, found that they more often than not forget to do so because of the overwhelmingly great number of changes. This of course causes many problems in managing the data, and they often find themselves working with old versions of CAD models. Students, at least, learn about the importance of keeping the working data up to date at all times.

4.6 Lack of students' skill and domain knowledge

This issue is usually found by instructors, but is often indicated by some students as well. Engineering students must be equipped with basic skills such as CAD modelling or simple finite element analysis (FEA), and industrial design students should be able to generate digital styling data using, for example, Alias Autostudio™. Also, basic knowledge on vehicle structure, vehicle dynamics, or package design is necessary for students to conduct the project. Since these skills and knowledge are not all taught in other courses, students have been found learning them during the course. This obviously causes delays in the project progress, so some of these skills are now taught before the beginning of the course or in early weeks, which alleviates the problem.

4.7 Imperfect digital styling data

This problem is well known to field engineers collaborating with designers. The styling data generated by industrial designers, such as Alias™ models, is not complete in the sense that a surface does not precisely match the adjoining surfaces. This is because industrial designers are only concerned with the overall shape, not the details. This, however, makes the conversion of styling models to CAD models extremely difficult. Engineers have to fix the style model before obtaining a solid model out of it.

This problem has been observed in almost every run of CoPro. Even though the importance of making precise styling models is emphasized, industrial design students in a hurry often fail to produce perfect models. Yet, it has a good educational value that both engineering and industrial design students learn that this type of problem may exist and has to be addressed.

4.8 Passive attitude of engineering students

When the concepts, as possible solutions to the problem, are sought, engineering students are often found to step back and wait for industrial design students to come up with an initial design idea. This is because they think that design concepts are something that must be derived by industrial designers, and that once a concept is given, then engineers would do engineering design as a means to realize it. It seems that they have been influenced by the practice of automotive industry that works this way, i.e. the design-led process.

It is stressed that the conceptual design stage aims at developing as many and as creative solutions as possible and, as such, it must be conducted by both engineering and industrial design students as a team. Partial, but significant, improvement is observed from this effort.

4.9 Problems unexamined in CAD model

Students often fail to find problems in their design until they make a mockup and test it, although they could have found and fixed some of these problems using the CAD model. A typical example of such problems is the interference between parts. This issue seems to result from two reasons: lack of CAD skills to use various checking functions, and lack of time before hurriedly making a mockup. No measures have yet been taken to deal with this issue, and so the mockup making is still playing an indispensable role in the success of the project.

5 Conclusions

This paper has presented a rather unique design project course which has been successfully run for seven times, with involvement of three departments: a Korean industrial design department, and a Korean and a German mechanical engineering departments. The main purpose of the course is to address the ever-increasing educational needs for future work forces to be capable of design-engineering interdisciplinary and western-eastern intercultural collaboration for product development. The outline of the course was first described, and then many findings from the seven runs of the course were explained and discussed from both students' and instructors' perspectives. Several conclusions can be drawn from them.

First of all, the intercultural and interdisciplinary barriers turned out not too tough for students to overcome by themselves. Interdisciplinary difference is not huge because the students are not real engineers or real designers. The authors believe that intercultural difference among students are rather easily overcome because they are more globalized than the older generations. This issue should thus be left to the students so that they can figure out how to handle it on their own; giving too much instructions in this matter may lessen or eliminate their valuable educational opportunities.

Secondly, it is however advisable for instructors to interfere with students in terms of the project schedule management because otherwise students tend to spend too much time at earlier stages. Proper schedule management should be achieved to make students experience all stages of design process with appropriate relative weights.

Thirdly, mockup making and offline activities are both crucial to make a design project successful. Digital models, in many cases, do not give the real feeling about what the design will look like and feel like; in particular, the technical feasibility can only be firmly validated using physical mockups or prototypes. In case where a design project is conducted collaboratively between remote sites, it is worth trying to arrange for offline activities because they make a drastic jump in building teamwork.

Finally, if such an interdisciplinary and/or intercultural design course is considered, close network among the instructors must be built first. This is because, without it, such a course will end up being only a set of different courses led by different groups of people, not a single integrated course.

Since most of the issues addressed throughout this paper are of rather general nature, it is hoped that this paper will be beneficial to those readers who are considering to develop a similar course.

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