LEARNING FROM AN INTERDISCIPLINARY AND INTERCULTURAL PROJECT-BASED DESIGN COURSE

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ABSTRACT
As globally distributed product development becomes increasingly common among major companies of today, educational tools for preparing our students for such work environment are increasingly needed. As one of the most effective tools for such a purpose, industrial design and mechanical engineering departments of a Korean university and a mechanical engineering department of a German university have jointly conducted a project-based, interdisciplinary, and intercultural product development course for four years. This paper presents observations made by the instructors and students during the project, and lessons learned from the analysis of those observations. It is hoped that these lessons will serve as useful guidelines for other institutions that are planning similar courses to cope with the ever increasing globalization and inter-disciplinary product development processes.

Keywords: Collaborative design, product design, interdisciplinary collaboration, intercultural collaboration

1 INTRODUCTION

Collaboration between industrial designers and engineers is crucial to develop products that have competitive advantages on the market. This collaboration, however, is known to be a time consuming process in which the two areas have to balance and negotiate their expertise-driven conceptions. This issue has been known for quite a long time, thus it is not difficult to find cases of educational institutions that conduct interdisciplinary courses or projects to prepare the students for such work environment [1-3].

Another more recent and important trend in the industrial practices is globalization. Employees in such companies have to collaborate with their colleagues in different countries and in different cultures. It has been arguably known that people in different cultures tend to think differently from each other, particularly Westerners and Easterners. They may different ways of thinking, presenting their ideas, reaching agreements, and even perceiving the world, as recently reported by Nisbett [4]. Therefore, students should be able to appreciate the differences, and be ready to use such understanding for successful global collaboration.

In order to well prepare our students for such a work environment having both interdisciplinary and intercultural natures, the authors of the present paper have jointly offered a project-based course for three years and are running the fourth one at the time of writing [5]. The title of the course is Collaborative Product Development or CoPro in short. The course involves three departments of two institutions with which the authors are affiliated: Chair and Institute for Engineering Design of RWTH Aachen University, Germany, and Department of Industrial Design and Department of Mechanical & System Design Engineering of Hongik University, South Korea. Each year's class of CoPro has ten students from each participating department. These industrial designers and engineering students shall be called 'designers' and 'engineers' for convenience throughout the rest of this paper.

CoPro, as a regular course offered during the spring semester, formally has three class hours per week, and has two components, lecture for one hour and project for two hours. In most part of the course, lectures are shared between the two universities by use of a video conferencing tool, and projects are collaboratively worked on using the same internet tool. In addition to this online collaboration, there are two periods for offline collaboration, in each of which one school visits the other for eleven days. In spite of the short duration, the offline interactions have been found extremely important in building teamwork and making progress. This paper presents the authors' and students' observations and lessons obtained from the projects, with focus on the project conducted in 2010.

2 PROJECT 2010 AS PLANNED

The project in 2010 aimed at designing and engineering an electric-manual hybrid tricycle, with final deliverable of a working prototype for each team. Details of the entire project as planned are presented in this section, starting with the design brief. In 2010, there was a client company that financially supported the project and also developed the design brief based on its own market trend research.

2.1 Design brief

The design brief given at the beginning of the course had the following requirements: the tricycle (1) must have three wheels for stability, (2) must be able to climb an uphill usually found on the main roads of mega cities (e.g. Seoul), (3) should have various optional features such as baby carrier, (4) should be mass-producible at affordable price (2.5~5 million Korean Won or approximately 1,700~ 3,400 Euros), and (5) should have attractive style. Further requirements were given as the project progressed. As in real life situations, the priority and the specification of particular requirements have been adopted to better meet the customer's expectations or due to time constraints. This practice caused confusions to the inexperienced students during the project.

2.2 Intended design process

Instructors of the course intended the project to follow the process delineated in Figure 1 that has focus on the flow of product data. First, each team should fix its specific target customer group and associated specifications (Task 1), and develop a most promising concept (Task 2) to satisfy the target users. Then, designers and engineers should develop digital styling models (Task 3, using Alias AutoStudio) and CAD models (Task 4, using Siemens NX), respectively; they, in these tasks, should discuss the feasibility of the models and conduct as many updating iterations as needed. Once these digital models are fixed, the team should build a physical mockup (Task 5) and, based on the problems found thereby, further modify and finalize the digital models (Task 6). These digital models are used to build a working prototype of the hybrid tricycle (Task 7).

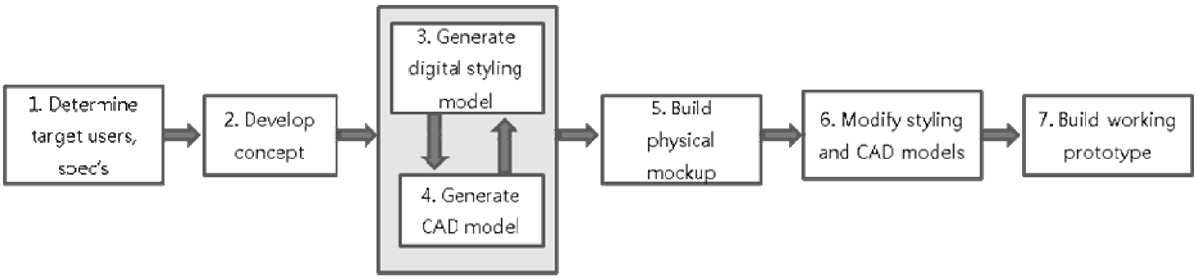

Figure 1. Intended design process with focus on product data flow

2.3 Team formation

The project began with four interdisciplinary and intercultural teams of students (named A1, A2, B1 and B2), comprising two groups (A and B). These two groups had different aims for the tricycle's usage: Group A for public usage touted as 'City Trike', and Group B for private usage called 'Personal Mobility Trike'.

The two teams in each group competed with each other until the design review, immediately prior to the mockup stage (Task 5). The team defeated in this design review was merged into the winning team in each group, forming a bigger team that would complete the project until the end. This inter-team competition within a group was intended to induce hard working of students, but it also had undesirable effects such as morale loss in the merged team, and difficulties in communication after merging.

3 PROJECT 2010 AS CONDUCTED

The project was conducted by following the process shown in Figure 1, but some deviations, with varying degrees among different teams or groups, occurred for various reasons. This section will briefly depict how the project proceeded in reality, with great emphasis on problems and failures in spite of the big success of the entire project. This is because we can learn lessons mostly from failures.

3.1 Deviations from the intended data flow process

As mentioned above, deviations of one team are different from those of another. This subsection will only describe the common or average deviations, which may be summarized as below.

(1) It took too long for the definition of target users and specifications (Task 1), over four weeks out of 17-week semester. (This is not really a deviation, but listed here for discussion convenience.)
(2) Generation and mutually-affecting iterative modification of the digital styling models and the CAD models (Tasks 3 and 4) were not conducted properly.
(3) Physical mockups were made without faithful reference to digital models (Task 5).
(4) Final digital models did not match the physical mockups (Task 6).
(5) The working prototypes did not completely match the final digital models (Task 7).

3.2 Outline of project execution

Even though the project did not faithfully follow the intended process, reasonably satisfactory outcomes were obtained at various stages. For example, concepts developed (Task 2) by Teams A2 and B2 are shown in Figure 2 through their styling models (Task 3). These two teams were selected in the design review as the winning teams for making mockups.

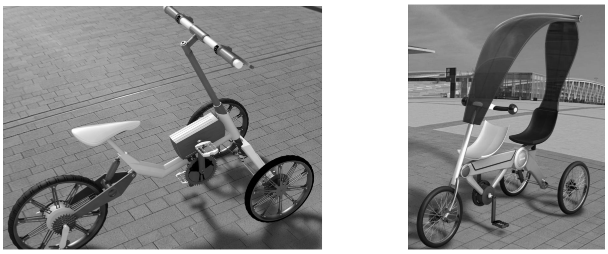

Figure 2. Digital styling models of Teams A2 (left) and B2 (right)

Without properly developed CAD models, physical mockups were made mostly based on the styling models. Materials used for mockups include foam, hardboard, wood, and acrylic pipes and plates. This mockup stage (Task 5) was conducted during the ten days that Aachen students visited Hongik University. A photo of the mockup built by Team B is shown in Figure 3 (left).

Figure 3. Physical mockup made of soft materials by Team B (left), and final working prototypes built by Team A (middle) and by Team B (right)

Based on the issues found during the mockup fabrication, the teams further developed their models, with or without incorporating these changes into the digital models, and updated the parts lists for building final working prototypes. Purchase of standard parts and fabrication of custom parts were conducted during the four-week period between the two mutual offline visits. The final assembly, with a lot of last minute design changes and purchase of missing parts, took place in Aachen in the eleven-day period. The working prototypes finally built are shown in Figure 3 (middle and right).

4 ANALYSIS OF PROJECT 2010

The project conducted in 2010 was analyzed through student surveys and in-depth discussion among the instructors. This section presents the combined findings from these surveys and discussions, beginning with the causes of deviations listed in Subsection 3.1.

4.1 Analysis of process deviations (problems with data flow)

Deviation (1) in Subsection 3.1, prolonged execution of Task 1, was attributed to the students' lack of knowledge about tricycle markets and inexperience in conducting such market research. The failure in collaboratively developing preliminary digital styling models and CAD models, Deviation (2) in Subsection 3.1, was attributed to the difficulties in converting Alias data into engineering CAD data. The state-of-the-art data conversion functionality of the software used has not provided adequate, integrated models. Therefore, only geometrical information was taken from the Alias data, and was used to develop the CAD model.

The other deviations, (3) through (5) in Subsection 3.1, are mostly due to the absence of complete CAD models. Because working prototypes had to be built at the end, engineering students had to generate 'new' CAD models many times, e.g. seven times for Team B, to catch up with the unusually frequent design changes. Though there may be several other causes, the most important and paramount cause of most of these deviations and others was the absence or lack of effective communication.

4.2 Analysis of communication

Effective communication *per se* among fifteen team members is not an easy task because of the big number of people involved, even though state-of-the-art computer tools such as the product data management system (PDMS in short; PTC Windchill in this course) and video-conferencing tool (Adobe Connect) were used. Communication among team members and with other parties of the project was not perfect, resulting in problems such as missing parts, purchase of wrong parts, and misfit among joining parts in the final assembly stage. Many causes for miscommunications were identified, and they may be divided into three categories according to their nature.

4.2.1 Disciplinary issues

Difference among students with regards to cultures and disciplines caused many problems to effective communication. Diverse ways of thinking between designers and engineers were observed problematic particularly in the stage of conceptual design. Most industrial design students, and some Korean engineering students, focused on nice-looking design, i.e. the appearance of the vehicle, whereas the other Korean engineering students and most German engineering students were much more concerned with the functions, structural integrity, and safety of the vehicle.

4.2.2 Cultural issues

As to cultural causes of miscommunication, two German-Korean cultural differences were identified. The first difference was about the way of acknowledging an agreement among people. Korean students tend to think that they have reached an agreement once all team members have verbally discussed a proposal in a positive mood and nobody has raised a strong opposition. On the other hand, Germans tend to not consider that as an agreement until it is formally declared as an agreement, either orally or in written form. The second type of cultural cause for difficulties with communication was the societal hierarchy in Korea [6]. A German student wrote that Korean students would not and could not directly discuss serious problems with their professors or strongly insist on seemingly good ideas that are against what professors said.

4.2.3 Human factors

Because team members are susceptible students, not professionals, human factors are expected to have relatively great impact on the inter-member communication, teamwork and thus project execution in this course. One of the two teams was a prominent example in that communication channels inside and outside the team, at least on the Korean side, were severely damaged by human factor issues between the Korean team lead and Korean team members. The resulting inharmonious teamwork was observed several times during the semester and was not resolved until the end.

It was also observed by most participating instructors that students in 2010 seemed not to talk or 'mingle' with each other compared to previous years. The authors attribute this mostly to the personalities of the team members (such as introvert and sociability) and the aggressiveness of the team lead. Also, the proportion of genders in the team was found important in CoPro projects.

For completeness, it should be mentioned that the client's involvement in decision making and mentoring has increased complexity of the project. With his background in industrial design, he provided valuable input in various stages, yet caused disruptions in the engineering workflow.

4.3 Analysis of project management

In general, students were pressed for time throughout the course. This was particularly so in the year of 2010 because of the broadened scope by the inclusion of a major task of building a working prototype. Student team leads could not manage the project as tightly and effectively as required by the project schedule guideline given by the instructors and the client. The sluggish progress of project was due to several factors, the most important being the fact that students spent too much time in identifying their target customers even though they could never be positive about their outcome.

Besides the five major design reviews where communication and feedback have been directly addressed, many consultations have taken place individually. Instructors' comments given during the consultation sessions often seem to have not been relayed or incorrectly been communicated to his or her teammates. This inevitably caused much confusion and harmed the student's eager for the project.

Finally, for timely progress of any project, students should have had background knowledge about the theme and should have been trained for various tools at the launch of the project. In spite of instructors' efforts to equip the students with such various knowledge during the course, effective use of such knowledge for the project turned out to be far from satisfactory.

4.4 Analysis of other comments

In contrast to the many problems identified above, some good practices were also found from the students' comments. Many students said, and all instructors agreed, that building physical mockups in the middle of the design project was extremely instrumental. Through building the mockups, students were able to see problems of their design, such as colliding parts, and accordingly modify it.

A good comment regarding conceptual design was made by an engineering student. Each of all members, designers and engineers, of a team produced five sketches in the conceptual design. In spite of the relatively poor sketching skill of engineering students, their sketches were good enough for team discussion in the conceptual design stage. This experience gave the engineering students strong confidence about their capability to visually communicate with designers.

5 LESSONS LEARNED AND GUIDELINES

Based on the analysis of the 2010 CoPro project and earlier ones, many lessons were learned. These lessons have been rendered as generic as possible and are presented below to help the readers who plan to conduct similar interdisciplinary and intercultural projects in a university setting.

5.1 Managerial issues

Management of an entire project may be conducted well by properly making and effectively utilizing the design brief, project schedule, and team structure. As to the design brief, its degree of details should be at an appropriate level because too much detailed requirements would tend to be changed too often or even eliminated downstream of the project whereas too rough requirements would lead to students' waste of time in clearly defining the problem.

The project schedule to be provided as a guideline at the outset of the project must be as detailed as possible. It is crucial to set an appropriate number of milestones in the project schedule and enforce them even though they often have to be adjusted with the project progress. Also, the number of design reviews accompanying formal or semi-formal presentations should be minimized because students often waste too much time in preparing presentation materials. Detailed team structure is often left to the students as in the CoPro projects. It is recommended that guidelines for the overall structure of the team should be given, with emphasis on the communication channels, both inside and outside the team.

The instructors, serving as mentors for the project, have to maintain live channels for communication with the students. Students' inquiries and suggestions must be answered, approved or rejected in timely manner. In cases where there are multiple mentors, it is extremely important that their responses should be consistent with each other, well documented, and available to all students.

5.2 Interdisciplinary issues

It is the instructor's role to combine different work processes of different disciplines, and organize them into a collaborative process such that the students interact with each other in constructive and complementary ways, and collaborate for their common goal. This may effectively be addressed by including desirable interdisciplinary interactions in the project schedule.

Different ways of communication may rather be easy to overcome because engineers can produce sketches that are not appealing yet sufficiently useful for communication. It may not be as easy for designers to learn the engineer's way of communication, yet it certainly is valuable to try so.

5.3 Intercultural issues

When students from different countries and different cultures participate in a project, many cultural conflicts may occur due to different ways of communication and of reaching a decision. Instructors should help students understand such differences by providing some basic information and also opportunities for cross-cultural interactions. Face-to-face social interactions seem to be the best way.

5.4 Team collaboration issues

Successful team collaboration begins with good team formation. There are several methods that have been developed for forming 'good' teams on the basis of people's mental and emotional characteristics. Though these methods may help, they are not recommended because team formation in actual industrial situations is often done otherwise. It may not be good to leave the team formation to the students, particularly in such hierarchical culture as in Asia.

Once the teams have been formed, clear and fair allocation of responsibilities among the team members is crucial. During the project, collaborative activities should closely be monitored by the instructors, and corrective measures should be taken when problems are found. Social interactions such as going on a picnic or eating together will definitely help build collaborative minds.

5.5 Students preparation and technical issues

Prior to or in the beginning stage of the project, students must be equipped with appropriate levels of technical knowledge and skills for the project scope and level of complexity. In addition to these tool skills, fundamental knowledge about the design theme is very important. Finally, the so-called soft skills, for effective communication, persuasive presentation, and smooth project management, are desired as well as the mindset to embrace different cultures.

6 CONCLUDING REMARKS

This paper has summarized various observations from interdisciplinary (industrial design and engineering) and intercultural projects jointly conducted, for three years, by a Korean university and a German university. The projects have successfully been conducted with excellent outcomes, yet many issues have been found. General guidelines have been developed by analyzing these issues and presented here. It is hoped that this guideline will help the readers planning similar projects.

The authors believe in the great benefits that the students can get from participating in interdisciplinary and intercultural projects, because such project setting resembles very much the real situations in the industry. With the ever-increasing tendency of interdisciplinary convergence and globalization of industrial product development, such projects will gain more and more importance.

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