An Idea Creation Support System to Develop Creative Problem-Solving Skills for a Cross-cultural Engineering Project

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The Cross-Cultural Engineering Project (CEP) aims to acquire synthetic problem-solving capabilities by promoting an international collaboration program. Thus, participation requires suggestions of procedures and proposals of creative solutions for resolving problems. In order to assist the activities of participants, this paper presents the Idea Creation Support System (ICSS) as a method to obtain attractive ideas and solutions for solving problems. For the creation of ideas, the ICSS consists of two understanding processes: problem understanding and Kando understanding processes. The problem’s requirements, defined from consumer needs and Kando quality (via the World Café method), are assigned as targets to enhance solutions. The Quality Function Development (QFD) matrix is then utilized with a contradiction solving method to define the essential solutions to satisfy all the problem’s requirements. The application of proposed methodologies enables participants to effortlessly obtain attractive ideas using the most effective solutions to solve problems.

Keywords: Cross-cultural Engineering, Idea Creation Support Systems, Kando Understanding, Quality Function Development (QFD)

1. Introduction

The Cross-Cultural Engineering Project (CEP) is an educational program for multicultural and multidisciplinary engineering and science students, which has been implemented and developed based on Global Project-Based Learning (gPBL)1, 2. The CEP was first proposed in the College of Systems Engineering and Science, Shibaura Institute of Technology (SIT), Japan, by adapting the activities from gPBL and increasing the targets to improve students’ capabilities. Hence, the CEP aims to improve and promote development according to four skills: communication, global leadership, intercultural understanding, and problem-solving3. In order to achieve the targets of CEP, the program is organized via international and multicultural collaboration under the conditions of meeting problems experienced by local communities and/or industries. Students who participate in this program are required to take part in a nine day program that uses progressive system thinking, the engineering method (system method) and system management, to acquire the problem-solving experience with an international perspective. Moreover, the participants undertake group activities to provide the concepts or technologies for solving problems using international and interdisciplinary teamwork with global communication.

The first CEP was held at Universidade NOVA de Lisboa, Portugal in July 2019, with activities organized with the 37 participants and 6 teaching assistants (TAs) who attended from four countries: Japan, Portugal, Spain, and Thailand. This year, the CEP has been expanded into three areas based on the educational effects of the gPBL: global problems in Southeast Asia, industrial and community cooperation in Japan, and innovative creation in Europe. The overall schedule for the CEP in Portugal in July 2019, is shown in Table 1. The participants were divided into six groups, with 6–7 members assigned per group under the condition of mixing nationalities based on a questionnaire (prepared by professors and TAs) for team formation. Since the process of defining a problem cannot be achieved until acquiring the solution/s, the CEP employs a synthetic problem-solving process (Figure 1) as a guideline for participants to work under the engineering system method.

Based on the synthetic problem-solving process, each group is required to consider and define the prob-
lem using keywords. Next, requirement analyses and definitions are employed, becoming essential to confer and create attractive ideas for the trending solutions to solve the outlined problems. It is necessary for the participants to perform group activities using analysis, solving, and proposing processes or technologies. The requirement analyses and definitions help the attendees achieve the target of their problem, which are presented on the last day of the CEP (commonly requires A3 material and presentation). On the final day, all participants have their CEP learning outcomes evaluated, based on the criteria to achieve the targets of the CEP and Progress Report On Generic skills (PROG) 3), 4).

During the CEP, the requirement analyses and definitions process is the most challenging step for participants (Day 2 and Day 3), and may be compared to a conceptual design process, which proposes useful and attractive ideas for survival. These ideas affect the quality of solutions, trending of technologies, and the satisfaction of new experiences and impressions to the customer or user. Therefore, this paper presents an educational application of Idea Creation Support System (ICSS) 5), 6) for the CEP in Portugal by performing with the Quality Function Development (QFD) matrix, which can be applied to acquire attractive ideas and solutions through effective systems thinking and engineering methods. The participants will create the ideas and solutions by expanding the keywords from the Kando understanding process to generate novel solutions for their theme. Then, the ideas and solutions for solving a problem can be reconsidered to help satisfy all consumer requirements via a contradiction solving method on the QFD matrix. This research newly showed the educational application for system design by combining the ICSS and the QFD matrix to acquire attractive ideas and solutions for doing activities through the CEP effectively.

2. Idea Creation Support System (ICSS)

A product or service is generally designed and created for satisfying customers, and is based upon the emotional experience of viewing a product or using a service. Thus, the conceptual design, which is a preliminary design process, is the most important step for creating attractive ideas to produce a successful product or service. As aforementioned, the CEP also expects the acquisition of essential ideas from participants under the synthetic problem-solving procedure and the proposal of new processes or technologies for solving the problem. This leads to participants conferring and considering attractive ideas, solutions, or technologies, via requirement analyses and the definitions process. Many methodologies have been studied and proposed for supporting creativity or engineering design across various applications 5) - 8). The ICSS is one such supporting method, which can be employed to guide participants to acquire new ideas and solutions based on effective systems thinking to solve problems (during the CEP in Portugal). The overall process of ICSS is displayed in Figure 2, and shows how to create new attractive ideas to an inexperienced designer. The ICSS consists of two

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Table 1 Overall schedule of the CEP in Portugal 2019

<table>
<thead>
<tr>
<th>Day</th>
<th>Activities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Day 1</td>
<td>Guidance for CEP, Ice breaking, Team-Forming, Confirmation of the theme</td>
</tr>
<tr>
<td>Day 2</td>
<td>Kando Quality (Emotional requirement) for finding and gathering needs and technologies using QFD</td>
</tr>
<tr>
<td>Day 3</td>
<td>Deployment of inventive solution using Contradiction Problem on QFD matrix</td>
</tr>
<tr>
<td>Day 4</td>
<td>Goal setting and design review (DR)</td>
</tr>
<tr>
<td>Day 5</td>
<td>Resetting goals and schedule of activities via DR’s comments</td>
</tr>
<tr>
<td>Day 6</td>
<td>Group activities for improvising education via mission from Professors and TAs</td>
</tr>
<tr>
<td>Day 7</td>
<td>Group activities (Research/Survey)</td>
</tr>
<tr>
<td>Day 8</td>
<td>Group activities (Production)</td>
</tr>
<tr>
<td>Day 9</td>
<td>Final presentation, Outcome assessments, Competency test</td>
</tr>
</tbody>
</table>

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Figure 1 Synthetic problem-solving process

Figure 2 Overall process of the Idea Creation Support System through the CEP program
understanding processes for idea creation: problem understanding and Kando understanding processes. In the problem understanding process, the consumers’ needs are expected to be used to provide possible solutions (based on those problems), and are required to be defined by the participants. The Kando understanding process is a step for gathering Kando elements using the World Café process\(^9\) to acquire attractive Kando quality. The results from both understanding processes are compiled and transferred to create new ideas and solutions under the QFD method.

The World Café process is a simple process that uses for gathering people or answers around questions. This process can increase the people’s capacity to work together with intercultural or multidisciplinary teamwork. So, the people will free from their personality and discuss with teammates to acquire solutions around the current questions. Thus, the World Café process is introduced and proposed for gathering the Kando elements and quality using the ICSS Kando understanding process. Kando is a Japanese word that translates as ‘standing for moving the mind’ in the Japanese dictionary. Thus, the Kando has defined it as the interaction of behavioral and reflective levels based on an experience of favorable or surprised larger than past experiences\(^5\). The Kando is useful for reconsidering the unexpected experiences under an emotional design to acquire attractive ideas or solutions through the CEP program. For the ICSS process, Kando is utilized for describing the emotional or favorable experiences of the consumers; dependent on whether something is unexpected or surprising. The overview of the Kando understanding process via the World Café method\(^5,6\) is illustrated

![World Café method](image1)

**Figure 3** World Café method for gathering Kando elements and quality through the Kando understanding process\(^5,6\)

![Kando elements which cause from emotional or favorable experiences and randomly put onto the round sheet](image2)

(a) an example of the round sheet in the first round of the World Café (before the classification process)

![Share](image3)

(b) final round of the World Café method for gathering Kando quality

**Figure 4** Kando understanding process via the World Café method for acquiring Kando quality
in Figure 3 (prior to gathering the solutions). There are four rounds of activities in the World Café method: three rounds for gathering Kando elements, and a final round for attaining Kando quality. In the first round of the Kando understanding process via the World Café method, each member in the team needs to write things and randomly put them onto a round sheet (as shown in Figure 4a) causing an impression; a so-called Kando element. The things that each member has to write in this round are nonessential to related to the theme. The participants can write any words from their feelings and impressions. The member has to share that feeling to the other team members within 15 minutes. Next, the team members (except the leader) visit other groups to listen to their feelings of each Kando element, while the leader shares the ideas of all Kando elements to guests within 10 minutes. In this round, there is a chance for discussion between the leaders and guests, allowing for the leader to write new Kando elements via Word of Mouth (WOM) communication5) during the discussion. The members then return to their team, and the leader share the new Kando elements, which were attained from the second round during the discussion with guests and team members.

In the final round of this process, each team needs to create a map and consider the results by splitting them into two axis categories: individual-share and past-future (Figure 4b). All Kando elements are divided on the map by relating the definition on each axis within 10 minutes. In order to gather the Kando quality, all Kando elements in the future-share area are essentially focused. The classification of the Kando elements are grouped based on each definition and similar types of words. There is no limitation for how many groups that suitable for grouping the Kando elements in the future-share areas, but they should be selected based on the reasoning of each element. The participants then imagine their feelings towards each group of Kando elements and select a representative word on a classification map (Table 2). The word that participants need to select should represent all Kando element’s overall meaning in each group corresponding to each emotion. The feeling classification map was presented by Takezawa et al.11 which shown in Table 2. The nearest word to how the participant feels is selected on the classification map, and subsequently used as a representative word for each group of Kando elements.

The words from the column of representative words are reflected in case the feeling classification map is used for grouping the Kando elements. These words are assorted and grouped for amplifying the emotions of stories in the middle class. Furthermore, the representative words are also classified and grouped based on their meaning for each. After classifying and selecting the representative words from the feeling classification map, the participants are required to give the reasons for selecting those representative words. In each group, the reasoning of the Kando elements to the representative words provides the Kando quality, and are transferred to the next process for acquiring solutions using the QFD matrix.

### 3. Quality Function Development (QFD)

As mentioned in Figure 2, the QFD12 is utilized after the solutions from the problem and Kando understanding processes are obtained for considering the satisfaction of customers’ requests by the supplier. The QFD is a kind of matrix (see Figure 5), which is composed of horizontal rows (describes the requirements of the problem based on Kando quality and consumers’ needs) and vertical column (fulfills the suitable solutions for solving the problem). Figure 5 showed the QFD matrix structure and examples to fulfill the solutions for needs and Kando qualities. A reader does not need to mind the correct meaning in this figure. In the horizontal rows, the requirements can be divided into two parts: needs from consumers and technology, and Kando quality. The participants have to investigate the consumer’s requirements and fill in the needs rows. The Kando quality, which is obtained from the final round of the Kando understanding process, is required to be added

<table>
<thead>
<tr>
<th>Major Class</th>
<th>Middle Class</th>
<th>Representative Words</th>
</tr>
</thead>
<tbody>
<tr>
<td>Receptivity</td>
<td>Abundance</td>
<td>Fill one’s heart, love, good, tears</td>
</tr>
<tr>
<td></td>
<td>Relish</td>
<td>Heart-warming, thank you, serenity</td>
</tr>
<tr>
<td></td>
<td>Relish</td>
<td>Sink deeply, tears of gratitude, twilight, lonely, touching</td>
</tr>
<tr>
<td></td>
<td>Fascination</td>
<td>Be fascinated, beautiful, majestic in spite of oneself</td>
</tr>
<tr>
<td></td>
<td>Touch a person’s heart, heart becomes hot, longing, scenery</td>
<td></td>
</tr>
<tr>
<td>Expressivity</td>
<td>Excitement</td>
<td>Exciting, wow, pound a heart, want to say something to somebody</td>
</tr>
<tr>
<td></td>
<td>Delight</td>
<td>One’s heart jumps, tasty, sympathy, hot dog! Fulfillment</td>
</tr>
<tr>
<td></td>
<td>Delight</td>
<td>Delight, hooray, after great pains</td>
</tr>
<tr>
<td>Neutral/</td>
<td>Grief</td>
<td>Feel shivers down one’s spine, panic, surprise, tension</td>
</tr>
<tr>
<td>Negative</td>
<td></td>
<td>Cannot bear, heartless, tremble, wailing</td>
</tr>
<tr>
<td></td>
<td>Awakening</td>
<td>Clutch one’s heart, heart is beating, tremulous, get goosebumps</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Come to one’s sense, unexpected, speedy, big</td>
</tr>
</tbody>
</table>

Table 2 Feeling classification map of Kando words10, 11
to the Kando rows. Together, both the needs and Kando rows should provide a proper solution in the form of a completed sentence (at least subject and verb) and reasonably correspond to each theme (see Figure 5). In this part, the results that are filled in the Kando rows imply the attractive requirements, with the suppliers or participants needing to find the solutions to satisfy these requirements.

The vertical column represents possible solutions for each problem corresponding to the requirements of the consumers’ needs and Kando quality. In order to find out the solutions, all possible results should be deployed and considered based on using various methodologies or approaches, such as the usecase scenario or sketching (Figure 6), to clearly describe the technology or procedure of solutions. Next, the relationship of each solution (vertical columns) with the requirements (needs and Kando-horizontal rows) are considered by the team members. There are only three possible answers, which are feasible for considering the relationship between the consumers’ requirements and solutions. If the solutions in the vertical column satisfy the requirements in the horizontal rows, a circle mark is allowed to be added to the QFD matrix. In contrast, a cross mark is added to the QFD matrix in cases where solutions are not satisfied. Furthermore, it is also permitted to keep the consideration process blank if there is no relationship between the consumers’ requirements and the solutions.

As a next step to acquire the most effective solutions for solving a problem via CEP, the contradiction solving method is also introduced to the participants. This method aims to improve solutions by satisfying all needs and Kando quality (indicated by all circle marks). The inventive problem-solving of the contradiction can be solved using other characteristics that would have otherwise been spoiled if improving a certain characteristic\(^{13}\). Therefore, a column of the solution indicates that the cross mark can be called a conflicted problem and mainly focuses on this process (Figure 7). The participants need to find the reasons and drawbacks of the solutions, which result in a conflicting problem. A process of reconsideration is then performed to enhance the solutions, thus satisfying all related needs and Kando quality. A rechecking process on the relationship between the new solutions and requirements (needs and Kando quality) is a final step using the QFD matrix in the ICSS. All circle marks indicate the most effective the relationship between solutions and requirements. After the contradiction has been solved, each team is

Figure 5 Components of the QFD matrix, with the need requirements representing Kando quality in the horizontal axis.

Figure 6 Solutions (functions) deployment on the QFD matrix.
required to find and propose new processes or technologies that can satisfy all solutions. This enables the provision of recommendations to answer a currently encountered problem. Moreover, the new processes or technologies that correspond to the solutions, are also confirmed to meet all the consumers’ needs using attractive ideas via Kando quality.

4. Evaluation Results

On Day 9 of the CEP, each participant has to fill out the evaluation sheet based on the motivational changes of each activity during the program. This evaluation sheet mainly consists of two sections: motivational changes, describing the alteration of the participants’ feelings towards each activity during the program, and comment or reason, which expresses their motivation for each activity. This paper aims to assess a participant’s satisfaction with a combination of the Kando understanding and the QFD matrix through the CEP using their motivational changes. Thus, the evaluation sheet enables the participants to provide their impression and evaluation of the efficiency of the ICSS to support them in finding convenient solutions. For investigation purposes, the motivational changes can be classified into three levels: positive, neutral and negative, which represents satisfaction, moderation, and unsatisfied, respectively.

The results showed that 77% of the participants had a positive motivational experience during the Kando understanding and the QFD matrix as it supported their ability to find attractive solutions easier than usual. So, the proposed ideas were confirmed that applying these procedures is an accomplishment for acquiring attractive ideas and solutions for solving the problem in the CEP because participants satisfied the ICSS process over 70%. Moreover, the ICSS consisted of a simple process that was easy to follow while acquiring results; reducing communication problems due to the onus placed upon international and interdisciplinary teamwork. However, the disadvantages of this system included the time limitations required to discuss opinions during each round of the World Café method, and the complications in finding the new solutions for conflicting problems. These results of the proposed processes also were reflected by 13% and 10% of neutral and negative motivations, respectively. Nevertheless, this provides the opportunity for improvement of the ICSS process, with the comments and motivations of the participants used as future recommendations.

5. Conclusion

The CEP is an international collaboration program, which mainly aims to acquire synthetic problem-solving skills from participants. The participants are divided into each team an asked to solve a local problem from communities or industries. This paper proposes the educational application of the ICSS in combination of the Kando understanding and the QFD matrix to be an effective system thinking process for the acquisition of new ideas and solutions. This is because the requirement analyses and definitions process are the most complicated method of synthetic problem-solving. The results of the problems related to understanding the process of ICSS is obtained from the consumers’ needs. The World Café method is utilized to gather the Kando element and acquires attractive ideas based on the Kando quality under the Kando understanding process. In this work, the feeling classification map is mainly proposed for the CEP activities and further improves for the other activities in future work. The results from both problem and Kando understanding processes produce the requirements and solutions under the definition and methodology of the QFD matrix. All suitable solutions should satisfy all requirements from consumer needs and Kando quality, and are checked using the contradiction solving method. Based on the contradiction solving method of the QFD matrix, the conflicted problems can be found and enhanced to acquire the most effective solution. Finally, the ICSS method is

![Figure 7 Contradiction method for finding the solutions to a conflict problem](image)
useful for an inexperienced designer, and it effortlessly acquires attractive solutions under the conditions of working with international and multicultural collaborations.

References

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