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Rolling Discussion Technique for Facilitating Collaborative Engineering Design Activities*

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The purpose of this study was to develop the Rolling Discussion Technique and to validate the developed technique process and principles. This technique is based on the concept of collective intelligence, which facilitates creative problem solving activities by sharing the ideas and thoughts of a large group of members within the class. An expert review and usability test were conducted as an internal validation method, and a field evaluation was used as an external validation method to partially confirm the feasibility and educational rationale. The results showed that the Rolling Discussion Technique suggested in this study can be applied as a useful discussion technique in engineering design education courses such as capstone design courses.

Keywords: Rolling Discussion; engineering design; knowledge sharing; collective intelligence; project-based learning

1. Introduction

Professional knowledge and analytical thought processes are the central elements in engineering education. Nevertheless, the focus has since been switched to comprehensive engineering education, where the integration of diverse field knowledge to think creatively has been emphasized, based on the core curriculum [1]. According to the Accreditation Board of Engineering and Technology [2], engineering design education deals with a sequence of processes involving designing a system, component, or process to develop the final product. This sequence requires an ability to think consecutively and universally, to solve problems and design creatively to make what is necessary. The instruction-learning method for engineering design is not limited to the introduction of knowledge and the transfer of information but it helps emphasize high order thinking processes by reviewing the overall processes: analysis, design, development and evaluation. This highlights the need for collaborative activities among individuals including personal intellectual activity.

Collaborative activity is defined as a learning activity, where the learners collaborate to achieve a common learning goal by taking responsibility for the process from the beginning [3, 4], and it is closely related to the learner's active participation and sharing of the socio-cultural view [5]. Until now, design education has focused on solving authentic and open-ended problems, as a team project learning method while emphasizing the three components: open-ended problem, teamwork and communication. Active interaction among members within a team has been observed but team to team interactions are rarely observed. Recently, the instruction method based on collective intelligence has become an alternative method to induce creative problem solving activities by emphasizing the learner-centred learning environments and the socio-cultural views of collaborative activities.

The aim of this study was to develop a discussion technique for receiving peer feedback and accepting a range of perspectives regarding the outputs (problem, process, and output) in each stage of the design activities based on the concept of collective intelligence. In particular, the literature on the general instruction design principles related to engineering design and collective intelligence were reviewed to obtain the principles for a new discussion technique and develop a specific procedure. The technique developed was applied to a real engineering design course, and its feasibility and effects were validated.

2. Theoretical backgrounds

2.1 Engineering design activities: problem, process and output

Engineering design can be defined as the systematic, intelligent generation and evaluation of the specifications for artefacts whose form and function achieve the stated objectives and satisfy the specified

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constraints [6]. The aim of the engineering design in the curriculum is to suggest an optimal solution for authentic open-ended problems through engineering design process. Therefore, the leading authors categorized the design into broadly similar sections using the terms, design 'problem', design 'process' and design 'types (outputs)' [7–9].

The major characteristics of a good design problem for introductory engineering design courses can be organized into the following three categories: open-ended, authentic and relevant. A design problem should be open-ended. Such a problem cannot be resolved mechanically or automatically using an already known method and there are a considerable number of solutions [6, 10]. Moreover, the problem requires the learners to conduct consecutive problem solving processes, such as problem analysis, idea generation, solution selection, verification and implementation. Design problems need to be real-life problems [11–13]. Primarily, the design problem should consider the course objectives, i.e. consider whether the problem can be solved through engineering problem solving processes.

Engineering design processes in engineering design courses consist of the following steps: recognition or understanding, analysis, generation, evaluation, implementation and communication. First, students in each team comprehend the engineering problem provided by the instructor or recognize the problem themselves. When the problem is created within the team, the problem will be evaluated using the three criteria (open-ended, authentic and relevant) stated previously. Second, problem analysis activities are performed, including information gathering, problem definition, cause analysis, identification of the criteria and specification of constraints. The relevant information including a prior technology search is collected [14]. The problem is defined as 3W (When, Where, What?) by specifying the current and ideal states [15]. Specific problem modelling is as follows: 'During 00 at (time), an unwanted phenomenon/operation is generated in (zone)'. The cause of the gap between the current and ideal states is then analysed. Subsequently, the design requirements to meet the final design goal and constraints to reflect on are specified [16]. Third, a range of solutions to overcome or eradicate the causes are speculated. During the process, brainstorming, SCAMPER, focal objects method, the contradiction principle of TRIZ and other creative problem solving techniques can be used. Fourth, the solutions brought up by the team members are evaluated to select the optimal solution. The optimal solution means a solution that can reach the ideal state that is set at the problem statement stage with the minimum incurred cost and effort [13]. The selected solution is then reviewed to determine if it solves the initially configured problem and if it has considered all constraints. Fifth, a model or prototype for the solution is produced. Sixth, the design report for the design process and the results are drafted, and the entire problem solving process and results are presented in front of colleagues to receive feedback.

The design output needs to contain originality and appropriateness. The design output can be viewed differently according to the design types but the patentability of the designs is a generally acceptable perspective when examining the output. For the design output to be patented, the following three conditions should be met: (1) it needs to be new, i.e. it has not been released to the public; (2) it needs to be capable of industrial applications; and (3) it needs to involve an inventive step [17]. Expecting freshman and sophomore engineering students to technically advance the output from engineering design courses is unreasonable. Therefore, the course's objective is judged as being achieved if the solution for the initially-stated problem is innovative and applicable in a real setting. This view coincides with the perspective of the scholars on the creative output [8, 18].

2.2 Knowledge creation and collective intelligence

The engineering design process seeks to create a new design that has not existed before, so any activity in engineering design processes includes some aspects of knowledge creation [19]. Knowledge creation is achieved when resources are collected, reading books or socially interacting with others for the design process. Collective intelligence is the concept that emphasizes the collective ability of people who can share and create knowledge.

Collective intelligence is defined as a process of idea derivation and creation for problem solving to overcome group thinking, which is the identical thoughts that the constituents of a group may have, through sharing information and knowledge with a range of people who have different levels of knowledge and experience [20]. According to Surowiecki (2005), collective intelligence is achieved when the following conditions for the diversity of opinion, independence, decentralization and aggregation are met [21]: (1) each person should have private information even if it is just an eccentric interpretation of the known facts; (2) the people's opinions are not determined by the opinions of those around them; (3) people can specialize and draw on local knowledge; and (4) some mechanism exists for turning private judgments into a collective decision. Collective intelligence is fulfilled when the following major properties of Web 2.0 are met (participation, sharing and being open) [22]. In other words, it is important to create a natural environment, where people can continuously ask and respond to a certain problem, and the collective ability to share and create knowledge can be improved through continuously activities [23].

3. Rolling Discussion Technique

3.1 Concept and instructional design principles

This study proposes the Rolling Discussion Technique as a collaborative knowledge creation method that emphasizes the interactions among the groups, and among individuals based on the collective intelligence.

Rolling discussion can be defined as a collaborative discussion method that helps find better solutions through collaborative conversation and reflection. Collaborative conversation occurs between members of different groups to share their experience and knowledge. Through a collaborative conversation, possible solutions are reflected in various points of view to generate a better solution. The Rolling Discussion Technique, which is a major factor forming collective intelligence, emphasizes the active conversations among many distributed people. In addition, the Rolling Discussion Technique is not limited to a knowledge formation process in the personal realm but encourages personal and collective knowledge formation through the sharing of information, knowledge, experience, and going through a range of convergent and divergent processes between the individual and group, and among individuals. In other words, personal knowledge formation reflects the socio-cultural nature, which is influenced by the discussion process among members in the group. In addition, through the synergy effect of individual and group interactions, personal knowledge formation can lead to the expansion of creative design education in which a new idea and useful products are created.

The major instructional design principles of the Rolling Discussion Technique that reflect the abovementioned characteristics are as follows. First, the common discussion topic that reflects the actual context should be set (*Principle of discussion topic contextualisation*). The discussion topic in the discussion class plays a leading role in motivating learners but also sets the purpose of the debate at the beginning of the discussion activity. Second, the learners should respect each other's experience and knowledge (*Principle of totality*). The learners, as members of a society, should have a positive attitude in contributing to society by solving engineering problems. This attitude stems from respecting the uniqueness of the individual learner, and the highest quality solution is drawn through discussion, seeking and revision. The learners share each member's experience and knowledge based on discussion, and the possible solutions are sought and revised. Third, the information and knowledge collected through discussion should be combined (*Principle of Combination*). As the learners conduct the discussion, they combine their collected information and knowledge from team members and develop a new view on possible solutions for the problem. Fourth, the newly formed information or knowledge is transformed as the knowledge of an individual or group (*Principle of Internalisation*). The newly drawn information or knowledge through discussion can be used as meaningful knowledge of both the individual and group through the reflective activities or transfer activities.

3.2 Procedures and methods of the Rolling Discussion Technique

The purpose of the engineering design course is to solve engineering problems creatively. This study applied the suggested Rolling Discussion Technique in three major issues related to the suggested engineering design. Table 1 lists the discussion questions related to the design problem, design process and design output.

The operating procedure for the rolling discussion on the discussion questions consists of three steps. First, as the preparation stage, team activities reflecting the discussion questions are organized and the roles of the team members are assigned. The host to lead the discussion by the team is decided.

At this step, the principle of discussion topic contextualisation is reflected. Second, as the rolling discussion stage, all team members except for the host will move to the other team and share ideas on the topic. Initially, the host explains the results of the team activity on the discussion topic. Subsequently, the members from other teams will suggest their experience or ideas by referring to the question lists (refer to Table 1) on the topic. While new team members suggest their ideas, the host actively listens and takes notes. Using an identical method, a new team will be formed at 2–3 rounds and perform a rolling discussion. When four people are in a single team, 20 minutes per round is sufficient but the instructor will be involved in observation and regulating the time. At this stage, the principle of totality is reflected. Third, as a reflection stage, the members move back to the original team and the host organizes the discussion matters and shares them. The suggested discussion matters will be reviewed and the discussion on whether to reflect the matters to the solution or not will be performed. An additional investigation on the idea that another team member suggested might be necessary. Consequently, the problem set by the team, problem

Table 1. Discussion topics of a Rolling Discussion

Topic	Discussion questions
Design problem	• Open-ended problem: Does the problem have a number of solutions? • Authentic problem: Does the problem require a real solution that has not been resolved in the past? • Relevant problem: Does the problem increase the engineering design ability?
Design process	• Analysis: Was sufficient information including prior technologies related to the problem collected? Was the problem stated by clarifying the current state and ideal state? Have the design requirements and constraints been specified to resolve the problem? Has cause analysis of the problem been done sufficiently? • Generation Have various solutions been suggested to eradicate or solve the causes? Have various problem solving methods been utilised? • Evaluation Has the optimal solution been drawn from possible solutions? Is the selected solution complete enough to resolve the problem? Does the selected solution reflect the constraints set at the initial stage of problem solving? • Implementation Has the model or prototype for the solution been created appropriately?
Design output	• Originality: Is the suggested solution novel or innovative? • Appropriateness: Can the suggested idea possible be applied in a real setting?

solving progress and the solution will be revised and complemented.

4. Validations of the rolling discussion technique

This study followed the development research methodology introduced by Richey and Klein to develop and validate the Rolling Discussion Technique [24], which was used to obtain peer feedback on the collaborative engineering design activities. Development research is divided into instructional method development and validation. The instructional design principles and the procedure for the Rolling Discussion Technique were developed from a literature review on the instructional design principles related to the engineering design and collective intelligence. The Rolling Discussion Technique was validated using the two main methods suggested by Richey and Klein [24]. Expert reviews and a usability test were conducted for an internal validation and the Rolling Discussion Technique was applied for an external validation to the collaborative design activities in introductory engineering design courses, and the course was evaluated to determine if the Rolling Discussion Technique was particularly helpful in finding possible solutions through collaborative design activities.

4.1 Internal validation: expert reviews and usability test

4.1.1 Validation procedure and instrument

The aim of the internal validation is to verify the instructional design principles, procedure and availability of the new discussion technique. First, an expert review is conducted to validate the instructional design principles and procedures. An instrument asks the expert reviewers to check the questionnaire according to a 4-point Likert scale (4 = fully verified, 1 = unverified). The questions regarding the appropriateness of the four instructional design principles, rolling discussion topics and a preparation-rolling discussion–reflection procedure are considered. The usability test for the Rolling Discussion Technique is targeted toward engineering professors who are in charge of creative engineering design courses and education experts. The usability test is revised and supplemented according to the suggestions made by Lee [25]. The four categories (efficiency, effectiveness, generality, applicability) are evaluated using a 4-point Likert scale (4 = fully verified, 1 = unverified). One semi-open question for each test, which asks to write some comments, is added.

4.1.2 Participants

In this study, six experts participated in the expert review to validate the instructional design principles and procedure of the Rolling Discussion Technique. The experts were selected from the field of engineering education and educational technology. Two experts (A and B) had 2-year teaching experience of introductory engineering design courses and a Ph.D. in engineering. Two experts (C and D) had teaching experience of engineering design courses and a Ph.D. in educational technology. Two experts (E and F) were research professors with a Ph.D. in educational technology. Eight experts, including the above six experts who participated in the expert review, took part in the usability test. An additional two experts (G and H) had a specialty in the instructional method and a Ph.D. in educational technology.

4.1.3 Data analysis

Both the expert review and usability test were analysed using the Content Validity Index (CVI) and Inter-Relater Agreement (IRA) suggested by Rubio *et al.* [26]. The IRA gives a score of how trustworthy the evaluation of the experts is. On a 4-point Likert scale, rating scores 1 (Strongly disagree) and 2 (Disagree) were paired up, and scores 3 (Agree) and 4 (Strongly agree) were paired to calculate the IRA to determine how homogeneous the ratings given by experts were [26–28]. The IRA was calculated by dividing the number of items that were evaluated equally by the total number of items. An IRA over 0.80 is considered to be valid [26]. The Content Validity Index (CVI) is the number of experts who evaluated each survey item as valid divided by the total number of experts [26, 28]. Similar to the IRA, when CVI is measured on a 4-point scale, it is calculated by looking at how homogeneous the experts rated the rating scores 1 and 2 versus 3 and 4. CVI provides a ratio of experts who evaluated the items to be valid. A CVI > 0.80 is considered to be valid.

4.1.4 Results

The results of the expert review on each principle and procedure for the Rolling Discussion Technique showed that the response to each category was on average 3.58 out of a 4 rating scale, and all the CVI and IRA values for each item were greater than 0.8. This shows that the principles and procedures of the Rolling Discussion Technique were valid and credible.

Table 3 lists the results of the usability test for the Rolling Discussion Techniques. The responses of the experts on four evaluation categories were 3.69 on average, and the CVI and IRA both confirmed the usefulness of the Rolling Discussion Technique as a discussion technique.

After validation, the experts provided some additional information that could contribute to the development of instructional design principles, discussion topics and procedures of the Rolling Discussion Technique. The suggestion that the definitions of the four principles need to be specified was reflected. The 'principle of totality' was highlighted as inappropriate and was changed to the 'principle of sociality'. In addition, the expert who applied the Rolling Discussion Method in an actual course stated that operating the engineering design process three times will reduce the time for team activities and suggested that the Rolling Discussion method should be applied at the problem design and final solution stages. On the other hand, a different expert, who applied the Rolling Discussion Technique in introductory engineering design courses targeting freshmen, stated that the students' concentration in class is normally low but the Rolling Discussion Technique has a positive effect on improving class concentration. In particular, this technique helped increase interest in the class.

Table 2. Results of the validation on the principles and procedures of the Rolling Discussion

Item		Expert response									
		A	B	C	D	E	F	M	SD	CVI	IRA
Instructional design principles	1	4	3	4	4	4	3	3.67	0.516	1	1
	2	3	3	4	3	4	4	3.50	0.548	1	
	3	4	4	4	4	4	3	3.83	0.408	1	
	4	3	3	4	4	3	4	3.50	0.548	1	
Discussion topics	Problem	3	3	3	4	3	3	3.17	0.408	1	1
	Process	2	4	4	4	4	4	3.67	0.817	0.83	
	Output	4	4	4	4	4	3	3.83	0.408	1	
Procedures	Preparation	4	3	3	4	4	4	3.67	0.516	1	1
	Rolling discussion	3	3	4	4	4	4	3.67	0.516	1	
	Reflection	3	3	4	3	3	4	3.33	0.516	1	

Table 3. Results of the usability test on the Rolling Discussion Technique

Item	Expert response											
	A	B	C	D	E	F	G	H	M	SD	CVI	IRA
Efficiency	4	4	4	4	4	4	3	4	3.88	0.354	1	1
Effectiveness	3	4	4	4	4	4	3	4	3.75	0.463	1	
Generality	3	3	4	4	4	4	3	4	3.63	0.518	1	
Applicability	4	3	4	3	4	3	3	4	3.50	0.535	1	

4.2 External validation: field evaluation

4.2.1 Validation instrument and procedure

The purpose of the external validation was to identify the educational rationale of the Rolling Discussion Technique. The developed technique was applied to a real creative engineering design course and the students were asked whether (1) the Rolling Discussion Technique was generally useful in collaborative engineering design activities and (2) if they were satisfied with the Rolling Discussion Technique as a learning method. The test items were developed considering the characteristics of the Rolling Discussion Technique. The validity of the test items were examined by two experts with a Ph.D. in educational technology. The test was assessed using the following two measuring scales: learning effectiveness (four items, $a = 0.79$), and satisfaction with application (four items, $a = 0.82$), where a indicates the confidence level. The participants were asked to rate their evaluation on a five-point Likert-type scale (strongly disagree/strongly agree).

4.2.2 Participants and data analysis

To analyse the educational validity of the Rolling Discussion Technique, the survey was conducted on students enrolled in the creative design course, particularly 26 students (22 males, 4 females) in the college of engineering at the I University. Among the 26 students, 9 were freshmen, 16 students were 2nd-year students and one was a 3rd-year student. The basic statistical analysis was conducted.

4.2.3 Results

An examination of the students' perception on using the Rolling Discussion Technique in the creative design course revealed a significant level of effectiveness. The comments showed that the Rolling Discussion Technique was helpful in problem solving, and it was good for accepting the range of perspectives of the other team members. On the other hand, more time for discussion was requested when returning to the original team.

5. Discussion

This study suggests the Rolling Discussion Technique to facilitate the exchange of ideas among the members in a team and among teams to overcome the present problems in existing research on the instruction–learning method of the engineering design curriculum. In particular, a discussion technique that facilitates the team-focused engineering design activities was developed, while considering that the current research on the instruction-learning method that guides the engineering design activities does not reflect the features of the engineering design. The following provides both theoretical and practical discussions.

5.1 Theoretical contribution

These results have three aspects of research significance in the theoretical realm. First, in this study, the discussion technique, as an engineering design instruction-learning method, was developed by comprehensively exploring previous research on engineering design concepts and characteristics. This study presents the design principles and procedures of the Rolling Discussion Technique among learners on engineering problem definition, problem solving processes and validation processes by considering the social context as open-ended, authentic and relevant. This study is significant because it reflects the design engineering characteristics and suggests a discussion technique unlike the current engineering design research focusing on PBL (Problem-Based Learning), which offers a comprehensive and general team learning method [29–35].

Second, this study suggests a discussion method that helps to share information and knowledge by accepting the range of perspectives of the members through a knowledge sharing process within the group and among the teams based on the concept of collective intelligence. The instruction method generally applied in the engineering design curriculum is a project or problem-based learning method, which solves problems based on idea sharing among

Table 4. Effects on the Rolling Discussion Technique

Items	M	SD
Learning effectiveness of the Rolling Discussion Technique		
The Rolling Discussion Technique helped in general.	4.46	0.50
The Rolling Discussion Technique helped select the good design problem at the design recognition stage.	4.15	0.83
The Rolling Discussion Technique helped review and revise the engineering design process.	4.34	0.74
The Rolling Discussion Technique helped produce and decide the final solution.	4.46	0.58
Satisfaction with the application		
By using the Rolling Discussion Technique, I have participated actively in design activity.	4.26	0.60
Participating in the rolling discussion is interesting and fun.	4.07	0.62
Through the rolling discussion, I could communicate with other members more so it was good.	4.46	0.51
I would like to recommend the Rolling Discussion Technique to other students who are involved in the team project.	4.26	0.77

team members within the team [29–31]. PBL can be used to identify and define the problem within the groups or the teacher defines the problem and the student uses this as a starting-point. On the other hand, the Rolling Discussion Technique method can be used to identify and define the problem through interactions with other group students' ideas or opinions. This process is essential for building and validating the authentic problem in the engineering design course. For example, in the stating-point, a group defines the initial problem. After defining the initial problem, through interactions with other groups they could build the authentic problem and determine if the problem is authentic or not. When the possible solutions are derived and the optimal solution is selected through idea exchange among members in the team, it is possible to commit an error by selecting the obvious solution that anyone can expect by compromising with the reality due to psychological inertia of a group. After defining the problem, team members draw an arbitrarily solution, and they converge to the optimal solutions of the problem from the sharing of various opinions through the rolling discuss technique. Through the input–process–output process of the Rolling Discussion Technique, the authentic problem is defined and set to draw a range of possible solutions, and the optimum solution should be selected and applied in an engineering design. Therefore, the Rolling Discussion Technique is a practical discussion technique based on the collective intelligence, which provides members with opportunities to view the problems from a range of perspectives and evaluate the solution.

The validity of the design principles and procedures of the Rolling Discussion Technique was examined comprehensively not only by the experts in the education method but also by the instructors in engineering design education, along with the instructors who applied the Rolling Discussion Technique in class. In the field of education, an expert review is commonly used as an internal validation method for a developmental study methodology, but clear guidelines are lacking and a commonly acceptable rule is applied when selecting the experts. Therefore, validity and usability can be achieved by including experts with knowledge and experience of applying the Rolling Discussion Technique, such as theoretical experts on instruction methods, and experts who have been involved in engineering design education.

5.2 Practical contribution

This study has the following significance in practical aspects. First, the design principles and procedures for the Rolling Discussion Technique provide practical guidelines for an effective instruction–learning method that offers feedback by each creative problem solving course in the engineering design curriculum. The difficulty in operating an actual engineering design curriculum is observed when the instructors need to invest a considerable amount of time and effort to provide feedback for each engineering design performed by the team. In this aspect, the Rolling Discussion Technique suggested in this paper is a useful instructional strategy that reduces the instructor's load of providing feedback by the team and provides the learners with a range of feedback from their peers. Previous studies related to providing feedback also reported the effect of the instructor's feedback and peers' feedback on the learning performance or learning achievement [36, 37].

The Rolling Discussion Technique can be implemented as a learning method that supports cross-disciplinary engineering design activities. In recent engineering design education, attention has been heightened to enhance the students' cross-disciplinary engineering design ability [38–40]. The cases related to cross-disciplinary engineering were discussed and shared [41–43] but there has been insufficient theoretical research on the cross-disciplinary engineering method. The Rolling Discussion Technique suggested in this study might be a useful learning method for applying cross-disciplinary approaches that derive engineering problem solutions in a range of perspectives.

6. Conclusion

Many engineering schools have offered design courses with open-ended problems. In particular, Capstone design courses are designed to give students the chance to apply the knowledge they have acquired throughout their education to real-world situations, open-ended, interdisciplinary challenges, so they can learn and apply the engineering design process: defining functional requirements, conceptualisation, analysis, identifying risks and countermeasures, selection, and physical prototyping. The Rolling Discussion Technique was proposed to improve the quality of the instruction method in engineering design courses.

Engineering design utilises engineering problem solving methods on a real problem by the following steps: recognition and definition of the problem, problem analysis, design of possible solutions, and selection of the solution, validation and presentation. Most engineering design activities have been implemented in project-based learning. These instructional learning methods are effective in facilitating interactions among the members within the team but it rarely provides team to team interactions. Therefore, based on the concept of collective intelligence, this study developed the Rolling Discussion Technique to facilitate creative problem solving activities by sharing the ideas and opinions of various people, and partially validated its rationale and educational feasibility using internal and external validation methods. The Rolling Discussion Technique suggested in this paper was verified as a discussion technique that can be applied effectively in engineering design courses. The educational rationale and feasibility of the relevant discussion method in this study was based on a survey of the learners' perception. Nevertheless, future studies will need to validate the educational effectiveness of the Rolling Discussion Technique using a meticulous experimental research methodology.

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