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Effects of Role Differentiation, Interaction, and Lapse of the Time on Shared Mental Models in e-Learning Contents Development Teams in Korea

Il-Hyun JO*
Ewha Womans University
Korea

The purpose of this study was to investigate the cognitive mechanism of e-Learning contents development projects on the basis of the Shared Mental Model theory perspective. To pursue the purpose, a theoretical model and several hypotheses were developed based on relevant literature. Thirty five (35) e-Learning contents development teams composed of 202 instructional designers from for-profit professional e-Learning companies in Korea were participated in this study. For the analyses of the fit of the Model and parameter estimations, Structural Equation Modeling (SEM) method was employed. As hypothesized, e-Learning contents development team members' interaction leads to higher SMMs which in turn facilitate member satisfaction within the team. Meanwhile, the frequency of interaction among team members decreases as projects progress.

Keywords : shared mental model, team-based instructional design, e-Learning

* Department of Educational Technology, Ewha Womans University
ijo@ewha.ac.kr

Introduction

Instructional design settings that most traditional ID (instructional design) theories and models consider are more logical and individual than social and collaborative (Jo, 2008a). Instructional design theorists, regardless of their epistemological backgrounds, assume that their typical clients are individual designers, not teams. However, in real world instructional design situations, especially in e-Learning contents development projects where a variety of expertise – e.g., instructional designers, graphic designers, and programmers - is required, team-based approaches are common. The discrepancy between the theories and real world practices would generate severe challenges to the instructional design research field. Without the provision of relevant theories that explain the unique collaborative aspects of the team-based collaborative instructional design practices, we may lose our credibility as application scientists.

There is growing evidence that the existence of shared mental models among the members of a work team has a positive effect on team processes and effectiveness (Klimoski & Mohammed, 1994; Mathieu, Heffner, Goodwin, Cannon-Bowers, & Salas, 2005). Shared mental models are *socially* constructed cognitive structures that represent shared knowledge or beliefs about an environment and its expected behavior (Klimoski & Mohammed, 1994). They influence team member behavior and improve coordination by enabling members to anticipate one another's actions and needs (Cannon-Bowers, Salas, & Converse, 2005). This notion is particularly important when work events are unpredictable or when frequent communication is difficult (Mathieu, Heffner, Goodwin, Cannon-Bowers, & Salas, 2005). However, empirical studies that examined the relationship between the shared mental models and the process of the team-based e-Learning instructional design situations are rare.

The primary purpose of this paper is to examine the mechanism of team-based e-Learning contents development project with the theoretical framework of shared

mental model. Two more specific goals are; 1) to generate a theoretical Model that provide theoretical structure of e-Learning contents development project on the basis of SMM perspective, and 2) to empirically validate the Model, and the pair-wise relational structure among the model's component factors such as team interaction, shared mental models, and member satisfaction. Mediating variables of the lapse of the time and intra-team member role differentiation were also considered. The results will provide theoretical and practical implications to the ever popularizing e-Learning contents development projects as well as general team-based instructional design practices.

Literature Review and Hypotheses

Shared mental model and team work

In the past decade, research on team effectiveness has burgeoned as teams are regarded as an essential part of organizations of all kinds. The final team performance is largely determined by the degree of exchanging, organizing, and utilizing diversified expertise effectively without conflict and miscommunication (Hsu, Parolina, Jiang, & Klein, 2007). E-Learning contents development is a typical team-based problem solving activity since it involves a series of complex problem solving activities in teams where members with diversified expertise are gathered together as a team to accomplish those complex tasks (Jo, 2008a).

The key for a project team to process information more effectively is to generate common understandings or shared mental models. Shared mental models (SMMs) are 'knowledge structures held by members of a team that enable them to form accurate explanations and expectations for the task, and in turn, to coordinate their actions and adapt their behavior to demands of the task and other team members' (Cannon-Bowers, Salas, & Converse, 2005; p.228). Team's SMMs, as literature (e.g.,

Marks, Zaccaro, & Mathieu, 2000; Mathieu, Heffner, Goodwin, Cannon-Bowers, & Salas, 2005) suggests, allow team members to anticipate one another's actions and to coordinate their behaviors, especially when time and circumstances do not permit overt and lengthy communication and strategizing among team members. Teams who share mental models are expected to have common expectations of the task and team, allowing them to predict the behavior and resource needs of team members more accurately (Cannon-Bowers, Salas, & Converse, 2005). Under the team and task circumstances such as e-Learning contents development projects as described above, members in teams must rely on preexisting knowledge to predict the actions of their teammates and to respond in a coordinated fashion to urgent and novel task demands to be more productive (Jo, 2008a).

However, the concept of SMM does not refer to a unitary concept (Cannon-Bowers, Salas, & Converse, 2005). Although the detailed breakdowns of mental model types are many, the many models can be viewed as reflecting two major content domains: (a) task-related model (e.g., the technology/equipment and job/task models) and (b) team-related model (e.g., the team interaction and team models) of the situation. A task-related SMM describes the content and structure of the team's specific tasks. A team-related SMM refers to how team members should interact with each other to accomplish the task and is adopted by many researchers to represent because different types of projects have similar teamwork SMM content (e.g., Johnson & Lee, 2008). This division is also consistent with the idea that teams develop two tracks of behavior- a teamwork track and a task work track (Mclntyre & Salas, 1995).

Hypotheses and relevant literature

As previous studies suggest, in project teams, members with different mental models about how tasks should be completed have a hard time coordinating their activities. To resolve these differences, team members need to exchange enough

information in order to negotiate a mutually agreed upon solution and means of achieving it. As information is accumulated through interactions such as observation, hearing others' explanations, or adapting one's own models, group mental models are thought to converge over time (Johnson-Laird, 1989; Klimoski, & Mohammed, 1994; Mathieu, Heffner, Goodwin, Cannon-Bowers, & Salas, 2005). Thus, researchers insist that interactions among members are strong predictor for the creation of the shared mental models. The more team members communicate with each other, the more likely they will form a common frame of reference and develop a shared mental model among the members (Klimoski, & Mohammed, 1994; Lurey, & Raisinghani, 2001). Empirical research supports that interactions among organizational members lead to similar interpretations of team- and task-events (e.g., Schein, 1992). These research findings lead the researcher to;

Hypothesis 1. Member interactions will positively predict the team-related SMMs.
Hypothesis 2. Member interactions will positively predict the task-related SMMs.

SMM influences team performance by decreasing the communication demands, thereby allowing team members to allocate cognitive load on the task at hand (Lagan-Fox, Anglim, & Wilson, 2004). Thus, once team members share enough level of mental models, there is little rationale to continue interactions, which consumes precious time and cognitive load that would be used for other purposes. For the professional intact contents development teams invited in this study that are expected to have some level of SMMs already, not much time should be necessary for their design projects except in the early stages where members need to understand the uniqueness of the new project. Therefore;

Hypothesis 3. Project lapse of time by month will negatively predict member interaction

Instances of reduced interaction and communication within groups may inhibit the exchange of task-focused or team-focused information, and thus delay or otherwise interfere with the creation of team-level cognition. Hypothesis 3 addresses this issue based on time factor. An additional factor that is to reduce the interaction is role differentiation factor. Such a situation can emerge when members decide to work independently of one another and have little role overlap. In group situations, one of the critical factors that is likely to affect the amount of interaction is the task structure or degree of role differentiation (Reichers, 1987), because team members communicate differently based on how their roles are structured (Rentsch & Hall, 1994). As noted by Edmondson (1999), the reflection and discussion required for team learning might also reduce team efficiency, a necessity in short-term project teams working to meet a deadline such as the end of the school semester or e-Learning contents development due. In this regard, Druskat and Kayes (2000) report a relevant case found in an MBA team project groups. MBA students who are required to meet deadlines and achieve high performance in project teams may result in short-term performance goals taking precedence over interactions and learning (Druskat & Kayes, 2000). In another study of the effects of structure on team interaction, teams in which every member had the opportunity to perform all of the subtasks communicated significantly more than teams in which the members divided responsibility for the tasks (Urban, Weaver, Bowers, & Rhodenizer, 1996). Since group interaction to coordinate work is partly a function of the type of role differentiation or division of labor within it, there may be situations that are less conducive to the formation of shared mental models. Hence the researcher can hypothesize,

Hypothesis 4. Role differentiation in teams will negatively predict member interaction.

Implementing group-based work holds the potential for reducing competition

and fostering cooperation among coworkers; individuals may be more satisfied under these conditions and produce more and higher-quality work as a result (Campion, Medsker, & Higgs, 2006; Fisher, 1981). Much conceptual work has been devoted to the idea that the use of groups can influence the satisfaction levels of group members (Campion, Medsker, & Higgs, 2006) and that satisfaction of individual groups members is an important measure of success and predictor of performance (Hackman, 1983). According to Hackman, team effectiveness includes three outcome components, (1) task output, (2) member's willingness to work together, and (3) member's satisfaction (Hackman, 1983). As such, evidence from the field studies suggests the importance of team member satisfaction on tasks and team members to team effectiveness (Campion, Papper, & Medsker, 1996; Cohen, 1994; Hackman, 1983).

As a sustaining social network, a professional performance-seeking team has additional responsibility beyond simply completing the assigned task; it must also care for its members and provide the right opportunities for personal development and growth. According to Druskat, SMM is a facilitating variable that enhances member satisfaction (Druskat, & Kayes, 2000; Druskat, & Pescosolido, 2002). Several other empirical evidences also indicate that the level of SMM in a team will contribute to the member satisfaction (e.g., Campion, Papper, & Medsker, 1996; Pierce, Kostova, & Dirks, 2001). Literature suggests that the ideal team member satisfaction condition is one where a predictable and reliable time and place for building relationships and exchanging perspectives and information exists, which is provided by the built-in SMMs. Therefore;

Hypothesis 5. Team-related SMMs will be positively predict the team member satisfaction

Hypothesis 6.Task-related SMMs will be positively predict the team member satisfaction

Based on the theoretical implications and empirical evidences, the researcher developed a theoretical Model that describes the causal relational structure of the variables involved. The Model with 6 directional Hypotheses is depicted as Figure 1;

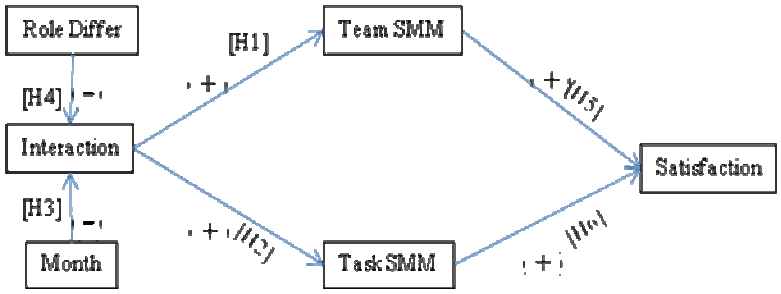

Figure 1. Research model and hypotheses

Method

Sample and procedure

The unit of analysis in the present study is the team, not the individual members. 35 e-Learning contents development teams in Korea participated in this study. The number of individuals all together was 202. Typical teams are composed of instructional designers, graphic designers, programmers, and system engineers. Size of the teams participated in this study was 3 to 15 with an average of 5.54.

The study employs a single cross-sectional design (Fraenkel & Wallen, 2008; p.300) to investigate the changes in the observed variables with one-time data collection. Since a preliminary interview with the sample teams indicated that typical e-Learning contents development project take about 3 months, the sample teams were categorized into three groups by the month of the project progress; 12 teams were 0 to 1 month old, 14 teams were 1 to 2 month old, and 9 teams at their

final stages of the projects. The level of SMMs, team performance, role differentiation, and member interaction were measured by the relevant instruments.

Measures

Shared Mental Models

To measure the SMMs of the participating teams, a revised version of the instrument developed originally by Levesque and her colleagues (Levesque, Wilson, & Wholey, 2001) was utilized. The revision was made mainly for a practical reason requested by the hosting e-Learning companies; to shorten the number of the items and to lessen subject's response time to the questionnaires. To make shortened but still reliable and valid instrument, several iterations of the selections of candidate items and following statistical tests – internal consistency using Cronbach's alpha and confirmatory factor analysis (CFA) using SPSS 15 and AMOS 7 - were conducted. Finally, 10 items, 5 for team-related SMM and 5 for task-related SMM, were selected for the study. Overall post-hoc alpha and RMSEA of the final instrument were .86 and .91, respectively. Examples of the final items were ranged from assessments of the team's communication processes (`Most of our team's communication is about technical issues.'), evaluations of the climate (`Voicing disagreement in this team is risky.'), and views of the team's structure (`Lines of authority in this team are clear.'). Items were assessed on a 5-point Likert scale as Levesque and her colleagues suggested.

Although SMMs have traditionally measured knowledge structures, it is argued that the construct should allow for the notion of evaluative belief structures of the member themselves. The work on cognitive consensus can assist in this regard (Mohammed & Dumville, 2001). 'Consensus' is different construct from 'consistency' (Mohammed & Dumville, 2001). Measures of consistency are indices of reliability or the proportional consistency of variance among raters. Examples of consistency indices include the Pearson's correlation coefficient *r*. High interrater

reliability measured by *r* can be obtained if ratings by *k* judges are different but proportional. Specifically, consistency indices attend on similarity of *rank* orderings of judges' ratings. Therefore, high interrater reliability can be obtained even when there is little manifest agreement between judges. For example, one rater may use values 97 through 100 (e.g., 97, 98, 99, 100), whereas another rater uses 1 through 4 (e.g., 1, 2, 3, 4). A correlational analysis of these ratings calculated by Pearson's *r* would reveal perfect consistency or similarity in the patterns of ratings, whereas an index of agreement would reveal minimum consensus (Jo, 2008b).

To assess the extent to which shared mental models had developed in each team, the researcher used a measure of intra-team similarity, instead of Pearson's *r,* as overall index of within team consensus (Cooke, Salas, Cannon-Bowers, & Stout, 2000) that looks at within group agreement (r_{WG}) (James, Demaree, & Wolf, 1984). r_{WG} is known as the most frequently used measures of agreement or consensus (Webber, Chen, Payne, Marsh, & Zaccaro, 2000). Mathematical representation of r_{WG} is;), where $r_{WG(J)}$ is the within-group interrater reliability for a group of *k* judges on a single item X_j, S^2_{xj} is the observed variance on X_j^2, and σ^2_{EU} is the variance on X_j that would be expected if all judgments were due exclusively to random measurement error (James, Demaree, & Wolf, 1984). It controls for response biases (e.g., leniency, social desirability, etc) that tend to inflate measures of group agreement (James, Demaree, & Wolf, 1984). This represents a dispersion measure, which refers to the variability within a group (Chan, 1998). To calculate several $r_{WG,}$'s, Microsoft Excel was used.

Role differentiation

Whereas the mental model measure looks at the level of perceptual agreement across a variety of variables, role differentiation measures the variance within group roles to determine the division of labor, i.e., how much the team members shared the duties of research, development, and organization of the team tasks. For instance, each team member's rate her own, and also each team member's

contribution to the project role using a 5-point scale. If a team's overall assessment is that every member made a 'moderate' or 'very little' contribution, the variance would be low, and the role differentiation would be low (i.e., they shared the task among all members). If instead, a team may have one member rated as contributing 'a lot', and another member rate as contributing `very little' to the same role, the division of labor in the group would be higher. As with SMM measures, $r_{WG,}$'s was employed as the indicator of member role differentiation in this study.

Team interaction

Each participant was asked to rate how much they had worked with other members of their team during the past months since their project using a 5-point scale that ranged from 1 (`not at all') to 5 (`a lot') for two different modes of interactions, one face-to-face interaction and the other electronic such as email or internet chatting. A team interaction score was calculated for each team by taking the mean of its members' interaction scores.

Team member satisfaction

To measure team member satisfaction, the survey instrument developed by Campion and colleagues (Campion, Papper, & Medsker 1996) was used with necessary revisions. The original instrument included 40 items on a wide range of topics, but the revised one had 10 items. A 5-point response format was also used, with higher arithmetic mean indicating higher satisfaction. Post-hoc Cronbach's alpha reached at .91.

Data analysis

To test the model fit and the individual Hypotheses 1 through 6, a Structural Equation Modeling (SEM) analysis was conducted using AMOS 7. By employing SEM procedures, the analyses are expected to control for measurement error by

fixing the random error variance to the product of the variance of the measured variable.

Before the primary analyses, a preliminary analysis of the data was conducted. The result revealed the presence of violations of normality indicated by several Kolmogorov-Smirnov's and Shapiro-Wilk's univariate normality and AMOS's multivariate normality indices. Also the sample size was smaller than required since the unit of analysis of the study was the team. To deal with these issues, special care was required for the selection of parameter estimation method.

Thus, a maximum likelihood (ML) procedure with 10,000 iterations of bootstrapping was employed for the estimation of model fit and other relevant parameter estimations. The rationale for hiring ML procedure is two-fold; 1) ML estimation has been the most commonly used approach in structural equation modeling, and therefore, is easy to understand for general readership, and 2) it has been found to be quite robust to a variety of less-than-optimal analytic conditions (e.g., small sample size, excessive kurtosis)(Hoyle,1995), which is obvious in the present study. In addition, a bootstrapping procedure was selected as an option to take more care of the sample size issue. Again, the sample size in this study is smaller than recommended by SEM researchers since the unit of analysis was the team. Bootstrapping calculates the parameter estimates of interest resulting in an *empirical* sampling distribution. In cases in which the assumptions of the classical statistics such as a small sample size are severely violated, the *empirical* distribution that describes the actual distribution of the estimates from this population that describes the actual distribution of the estimates from this population will be substantially accurate than the *theoretical* distribution.

Results

Correlational results

Presenting a correlation matrix permit the interested reader to recover the variance matrix. In reporting these data rounding to three rather than the customary two decimal places are presented to take full advantage of the precision offered by SEM program as recommended by Hoyle (Hoyle, 1995).

Table 1. Correlations matrix

Factor	1	2	3	4	
Lapse of Time	1				
Role Differentiation	.121	1			
Interaction	-.102	-2.33	1		
Team-related SMM	-.011	-.021	.365	1	
Task-related SMM	-.112	-.023	.243	.112	1
Satisfaction	-.031	.063	.324	.563	.405

Model fit

Major criteria indicators of the overall adequacy of the model fell within reasonable bounds. Table 2 summarizes the estimates of the major fit accompanied by the major criteria indices.

Table 2. Model fit indices

	NFI	CFI	RMSEA		
			Total	LO90	HI90
Observed	.902	.920	.097	.092	.121
Fit criteria	>.900	>.900	<.100	>.050	<.100

Individual hypothesis test results

Since the model fit was evidenced by the data, tests of the individual hypotheses followed. As shown in Table 3, these predictions were mostly supported. For Hypotheses 1 and 2, the researcher proposed that team member interactions would predict teams' SMMs including team-related and task related. Data supported the two Hypotheses. For Hypothesis 3, as expected, the degree of team interactions did reduced significantly over time. Hypothesis 4 was also confirmed by the data. The degree of role differentiation predicted decreased team members interactions over time. If they know what he/she has to do clearly and precisely by the job differentiation or division of labor, individual members find decreasing benefit from interactions. For Hypotheses 5, which investigate the possible effect of team-related SMMs on member satisfaction, were confirmed by the data. As expected, shared mental models on other colleagues help members satisfied in doing their jobs. However, Hypothesis 5 on the relationship between task-related SMMs and member satisfaction was not confirmed.

The overall results are summarized as shown in Table 3.

Table 3. Hypotheses test results

Hypotheses	Standardized estimates	CR	p	Confirmed
1. Member interactions → (+) Team-related SMMs.	.094	2.814	.006	Yes
2. Member interactions → (+) Task-related SMMs.	.044	2.347	.014	Yes
3. Lapse of Time → (-) Member interactions	-1.247	-3.471	.001	Yes
4. Role differentiation → (-) Member interactions	-2.011	-2.215	.020	Yes
5. Team-related SMMs → (+) Member satisfaction	1.553	6.606	.000	Yes
6. Task-related SMMs → (+) Member satisfaction	.311	1.581	.094	No

Discussion

Interpretations of the results

From the present study, several specific findings were recognized as below:

The first and most obvious point to make is the fact that member interaction was found to be a prime predictor for the development of team-related and task-related SMMs. As proposed by Cannon-Bowers et al. (1998), knowing and understanding one another seems to enable effective knowledge sharing and open communication in a team. This finding suggests that spending some time focusing on becoming familiar with one another can have a positive impact in e-Learning contents development project teams.

Second, creating clear role differentiation by the division of labor was found to e a negative predictor of member interactions. This suggests that as role specialization within the group increased over the course of the project, the amount of time team members spent in meetings and other forms of communication decreased as much. Previous research with project teams has found clear work procedures to increase team efficiency (Ancona & Caldwell, 1992). The findings in the present study suggest that such efficiency has a negative influence on the amount of interactions that are critical for knowledge sharing and reflection that go on in a team. This finding is consistent with research conducted by Langer (1997), which revealed that learning is hindered by clearly mapped-out processes because they reduce mindfulness or the amount of thought and attention paid to the process.

Finally, team-related SMM was found to be a very strong predictor ($\beta = 1.544$, $p=.000$) of team satisfaction. However, task-related SMM was not associated with team satisfaction. One possible reason for this result could be found from the literature that address the diminishing effects of task-related SMMs on member satisfaction (e. g., Levesque, Wilson, & Wholey, 2001). As the theorists suggest, professional team members usually have a certain level of task-related expertise

already by their previous collaborations in the similar projects (Hinsz, Tindale, & Vollrath, 1997; Michaelsen, Jones, & Watson, 1993). Thus, the team members may not feel extra satisfaction due to task-related SMMs. In other words, a kind of ceiling effect was operating. The term ceiling effect refers to an effect whereby a measurement cannot take on a value higher than some limit or "ceiling", which is imposed not by the phenomenon being measured, but rather by the finite nature of the measuring instrument.

Conclusion

The purpose of the study was to investigate team-based e-Learning contents development activities on the basis of the shared mental model theory. To pursue the purpose, a theoretical model and several causal hypotheses were developed based on relevant theoretical underpinnings and empirical findings.

The general finding of the present study was that theories and empirical findings on the SMM framework can be useful in understanding the collaborative and interactive dimension of team-based instructional design and development projects. Further, the relevance of the Model suggested by the researcher was confirmed by the data, which emphasizes the effects of the interactions on SMMs of e-Learning contents development teams, and the SMMs further predict team member satisfaction. In addition, member role differentiation and project progress were found to be mediating factors that negatively interact with member interactions on SMMs.

Several specific findings were also recognized. One of them is the differential effects of SMMs on team member satisfaction. This differential effect seems to have interaction with characteristics of the teams: type of SMMs predict greater effect on the comparatively weaker type of SMMs of the team. However, this conjecture needs to be empirically investigated by the future research. Another

specific finding in this study was the mediating effect of team role differentiation and progress. As member roles are clearly defined, and as project progresses, extra interactions do not seen necessary by the content development team members.

Like all research, the present research is limited in a number of aspects. First, the measure of SMM –like other measures of SMMs (e.g., Johnson, Lee, Lee, O'Connor, Mohammed, & Huang, X., 2007; Levesque, Wilson, & Wholey, 2001; Marks, Zaccaro, & Mathieu l, 2002; Mathieu, Heffner, Goodwin, Cannon-Bowers, & Salas, 2005; Rentsch, & Klimoski, 2001) –depends on individual team member's responses with fewer items than original instruments. Even though necessary statistical tests were conducted to investigate the quality of and modifications for the instruments used in the study, alternative instrumentations will help better understanding by methodological triangulation. Second, team performance, an ultimate outcome variable, was not included in the model. Third, no cross-validation that could strengthen the validity of the model was made. When the sample size is small, even though model fit indices and *p* values meet the set criteria, cross validity of the model should be suspicious. Therefore, cautions should be exercised to interpret the result of the study.

In line with the identified limitations of the present study, several suggestions for future research are provided. First, cross-validation using criterion samples should be conducted for the generalization of the model. Second, for more practical purpose, strong and reliable antecedents of the SMM other than interactions need to be identified. Team building effort for the ID team members, especially in their early developmental stage, could be a testable antecedent (Michaelsen, Jones, & Watson, 1993). Third, team performance variables should be included in the model structure. Member satisfaction is a strong predictor of the performance, but at the same time, it is a part of the performance. However, if direct performance indicators such as the e-Learning grades awarded by the KRIVET(Korea Research Institute for Vocational Education and Training) are included in the model, the study will gain greater strength.

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Il-Hyun JO

Assistant Professor, Department of Educational Technology, Ewha Womans University. Interests: HRD, Social network analysis, Knowledge management, e-Learning, Storytelling, GBS

E-mail: ijo@ewha.ac.kr

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