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An effect of multidisciplinary design education: creative problem solving in collaborative design process

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Abstract: *This study verified whether the students who received multidisciplinary education can be considered to have attained more creative problem-solving abilities than the students who majored only in design, based on their completion of a project after teaming with students from various other departments. When it is heterogeneous and in the in-depth discussion stage, the EMT(heterogeneous teams, including multidisciplinary design major) produced more creative output than the EDT(heterogeneous team, including design-only major) as a result of an experiment. Therefore we compared the creative process of the EDT and the EMT in the in-depth discussion stage of the heterogeneous groups by the conversation analysis. In the problem-solving approach, the EMT focused more on context and the multidisciplinary students considering much more diverse aspects of design content. Analysis of the group activity process showed that the EMT and multidisciplinary students actively engaged in idea generation and review & summary. As such, this study was able to confirm that students who received multidisciplinary design education, when they form a team with various other majors to do a project and in the in-depth discussion stage, show differences in creative process to solve problems and more creative output than students majoring in design only.*

Keywords: group creativity, multidisciplinary design education, design process

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Introduction

A study by Denton, published in 1997, examined some factors involved in the planning and practice of multidisciplinary team-based design project work at undergraduate level. The study reports that since industries increasingly require more multidisciplinary project work than monodisciplinary team work, the demand for design college graduates with experience in the former is increasing. Several British universities, including Central Lancashire University, which offered education programs that combined design and other academic disciplines, were mentioned as subjects in that study investigating the components required for inclusion in multidisciplinary team design project planning. For more than a decade, therefore, beginning in countries such as Great Britain, the need for multidisciplinary design education has been felt and related research and education programs implemented. Following this trend, Korea also launched in 2007 the Capstone Design project, which marked the start of multidisciplinary design school development policy. The Capstone Design project was mainly a program for fostering the comprehensive problem-solving abilities of students by bringing design students together with students from other departments to form a single team and having this team complete a project in partnership with a corporation. Intensifying this program format further, the multidisciplinary design school development project was launched in 2009. The aim of this project was to nurture design talent with creative and integrated problem-solving abilities. It consisted of combining the curricula of three or more departments from different academic disciplines and, based on this, creating a new major within the department of design, as well as operating a related industry-academy cooperation program. In the present study, we seek to verify whether, after three years of this project, the students who received this multidisciplinary education can be considered to have attained more creative problem-solving abilities than the students who majored only in design, based on their completion of a project after teaming with students from various other departments.

Group Creativity

At the group level, creativity is a function of group processes in addition to group composition and group characteristics (Shalley & Gilson, 2004; Woodman, Sawyer, & Griffin, 1993). The input-process-output model (Cohen & Bailey, 1997; Shalley et al., 2004; Zhang et al. 2011) suggests that a group's creative output is a result of the group's processes. Group creativity performance can be viewed as the result of interactions among several important components or dimensions of creativity. These various components or elements can be categorized into Input, Process and Output. Figure 1 diagrams the relationships among these components (Siau 1995).

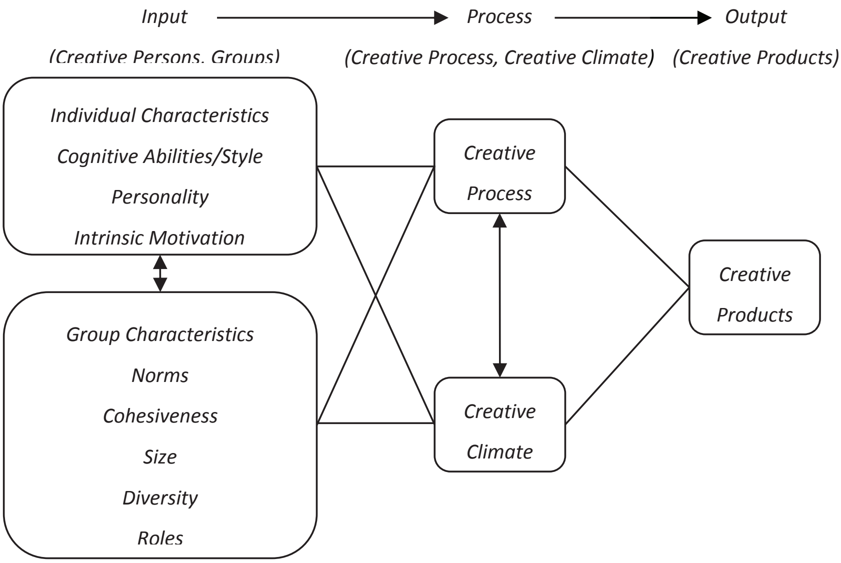

Figure 41. *The relationships among creativity components (Siau 1995, p204)*

In seeking to understand the factors contributing to work group creativity, Zhang et al. (2011) explored the roles of two different leadership styles that leaders play in group creativity through influencing internal group processes, i.e., collective efficacy and knowledge sharing among group members. They included group diversity in members' age, gender, education, and job function as control variables because group creativity may be affected by group size (Curral, Forrester, Dawson, &West, 2001), members' group tenure (Shin & Zhou, 2007), or group type (Shin & Zhou, 2003).

With respect to design, creativity is the process of making a product that will be accepted as lasting, useful and satisfactory by a group gathered together for a specific purpose. The five components that must be included in the theory of creativity are person, problem, process, product, and climate (Taylor 1975). Taggar (2002) and West et al. (2003) beg the question of what produces these creativity-generation processes. Taggar investigated the interaction between group members' individual dispositions (e.g., cognitive ability, openness to experience, and conscientiousness) and group processes (e.g., involving others, providing feedback, and effective communication) in the creation of products by groups of college students. West et al. found that group processes (e.g., group participation, commitment to team objectives) consistently predicted group creativity.

Creative performing and team communication

Diversity research suggests knowledge complementarity as a creativity-enhancing mechanism (Jackson 1996, p. 60). New perspectives are explored in response to dissent, and new ways to look into an issue that is disputed (De Dreu and Beersma 2001, p. 270). Some research has found that diversity is related to higher creative performance (Andrews, 1979; Payne, 1990; Visart, 1979). Increasing diversity should increase the range of knowledge, skills, and perspectives available within a group that should positively impact creativity (McLeod & Lobel, 1992; Pelled, Eisenhart, & Xin, 1999). A series of studies conducted by Hoffman and colleagues (Hoffman, 1959; Hoffman et al., 1962) found that diverse groups experienced more conflict and consequently were stimulated to search for different answers and alternative solutions. However, stressing the benefits of diversity may cause the difficulties of heterogeneous team collaboration to be underrated. Such difficulties have frequently been reported, particularly communication, coordination, and efficiency problems. In the 'pessimistic' view, diversity is seen as problematic as it introduces differences that produce communication problems and tension, thus hindering effective teamwork (Reagans and Zuckerman 2001). We need to explore how the creative process of students who received multidisciplinary design education changes depending on group diversity compared with students majoring in design only. Therefore we compared the creative performance of multidisciplinary design students and design-only students by dividing the subjects into a homogenous group comprised of same majors and a heterogeneous group made up of different majors.

The creative performances of the design teams show a difference between the initial design brainstorming stage and the subsequent more in-depth discussion stage. Rosalie and Jerry (2008) measured the design team performance in terms of creativity of design and quality of design and divided the teams into high performing teams and low performing teams. The analyses of their communications showed that high performing teams spent less time in brainstorming activities. It was found, however, that the high performing teams conducted more in-depth discussions. Irina and Vanessa (2009), in their study on understanding the communication mechanisms of collaborative design teamwork, analyzed the visualization in a 15-minute brainstorming session and the subsequent session separately. In this study, the design process was also examined by dividing it into an idea generation stage and an idea deepening stage.

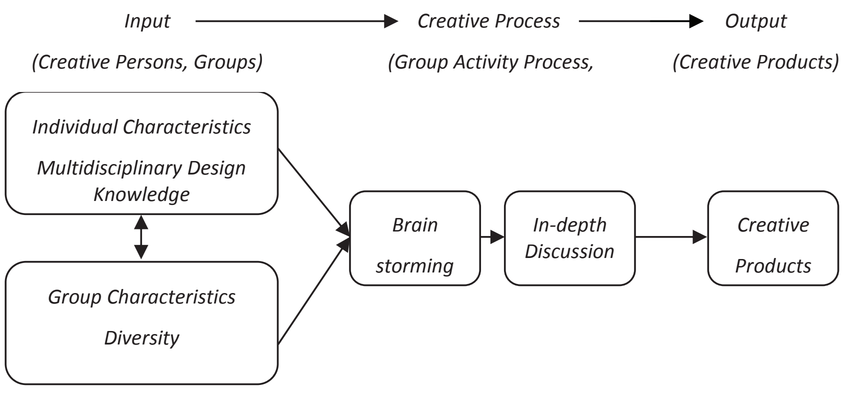

Figure 2. *The research model*

Method

The experiment lasted a total of 100 minutes, proceeding in the order of individual creativity examination (30 minutes) and design task (70 minutes). Each group was provided with 10 sheets of B4 paper, pencils and erasers as the tools needed for the experiment. The entire process was videotaped with two cameras per group.

Participants

The experiment participants comprised 12 junior design majors from the multidisciplinary design education program, 12 junior design majors from the traditional design education program, and 12 sophomores to seniors from other departments for a total of 36 students. They were grouped into 12 teams of three. Of these 12 teams, 6 teams were heterogeneous with each group consisting of 1 design major and 2 non-design majors, while the remaining 6 teams were homogenous with each group made up of all traditional design majors or all who participated in the multidisciplinary education program. The multidisciplinary design education students all participated in the two-year multidisciplinary education program and have industry project experience ranging from 2.5 to 11 months. The non-multidisciplinary program participants were selected to have as much as possible similar GPAs, and the non-design majors in the heterogeneous groups, similar majors and class years. Also, in order to obtain a similar level of interest in design for the non-design majors, the subjects were chosen from students taking elective courses in design who wanted to participate in the experiment.

Table 1. Form a group

Major / Design Education	Homogeneity	Heterogeneity
Design	· 3 homogeneous design teams(ODT) · Each team members : 3 design majors	· 3 heterogeneous design teams(EDT) · Each team members : 1 design-only major + 2 non-design majors
Multidisciplinary Design	· 3 homogeneous multidisciplinary design teams(OMT) · Each team members : 3 multidisciplinary design majors	· 3 heterogeneous multidisciplinary design teams(EMT) · Each team members : 1 multidisciplinary design major + 2 non-design majors

Task

Dorst, Kees and Cross (2001), in their study on creativity in the design process, stated that the industrial design domain is particularly interesting for the study of creative design because it calls for new, integrated solutions to complex, multidisciplinary problems. They argued that the design task for creativity evaluation needs to be challenging, realistic, appropriate for the subjects, not too large, feasible in the time available and within the sphere of knowledge of the researchers, and that the problem is typical as far as industrial design practice is concerned, in that it calls for the integration of a variety of aspects. In a similar vein, the present study examining design creativity selected the task that can reveal integrated problem-solving ability. The task was also something on which the major of design had little impact and which was easily accessible to non-design majors in everyday life. The topic given as the design task was "It is 7 PM in the evening. How can we make people feel better after work?" The time allotted to perform the design task was divided into experiment A and experiment B. Experiment A (brainstorming) required sketching or writing the description of the ideas produced in the group during the 20-minute period, without limitations and consideration of implementation methods. Experiment B (in-depth discussions) required, within the 50-minute period, choosing an idea from the prior session (Experiment A) or a new idea and further developing it based on a specific method for its realization and then writing and submitting its design background, design concept, and design solution image.

Torrance Tests of Creative Thinking (TTCT)

In order to verify whether an individual's creativity affected group creativity, individual creativity tests were given. The participants each performed three actions: receiving one TTCT Figure A test sheet and following the test giver's instructions, completing the figure and attaching the name during the given time. The TTCT results confirmed that in both the homogeneous groups (P-value: 0.725) and heterogeneous groups (P-value: 0.294) there were no statistically significant differences between the individual creativities of design-only students and multidisciplinary design students.

Creativity Measure

Design output creativity was judged by three experts through prepared evaluation sheets. The judges consisted of two professors and a doctoral candidate in design. The evaluation sheets were prepared based on the Korean creative product evaluation tool (Kim and Lee, 2004, p. 305) developed by modifying Besemer's (1999) Creative Product Analysis Model (CPAM) and Creative Product Semantic Scale (CPSS) to reflect the cultural peculiarities of Korea for the purpose of assessing the degree of product creativity. The evaluation tool is structured with three components and eight sub-components - novelty (surprising, original), resolution (logical, useful, valuable), style/elaboration and synthesis (organic, well-crafted, elegant), with each sub-component having 2~7 questions. The responses to these questions were evaluated on a 7-point scale and the average of the three components was taken as the 'creativity' measure. Separately from this, a single 'score' question was established to assess the overall creativity of the design. It asked, "On a scale of 100, how many points would you give to this design?"

Result of the evaluation of products

The output evaluation results showed the Chronbach's α coefficient value, which signifies the degree of congruity among the 3 judges, to be 0.6 or higher for all evaluation items, indicating high measurement reliability.

Table 2. The inter-rater reliability of the output

	Novelty	Resolution	Elaboration & Synthesis	Score
Experiment A	0.767	0.722	0.696	0.892
Experiment B	0.844	0.897	0.864	0.815

In the homogeneous groups, the differences in output creativity of the design-only teams and the multidisciplinary teams were shown only in elaboration & synthesis, as given by Table 3. In the heterogeneous groups, as presented in Table 4, the differences were shown in resolution; average, the average of the three components (novelty, resolution, elaboration & synthesis); and score, indicating the overall degree of creativity. But these differences all appeared only in experiment B. There were no statistically significant differences shown in experiment A, since the p-value was found to be much greater than the significant level 0.05. In other words, for idea generation during a short time period, there were no differences between the EDT and the EMT, but in terms of deepening a small number of ideas overtime, the multidisciplinary teams produced more creative outputs.

Table 3. The evaluation of output creativity (homogeneous groups)

	Experiment A			Experiment B		
	ODT	OMT	P-value	ODT	OMT	P-value
Novelty	3.84	3.87	.954	3.86	4.69	.113
Resolution	4.40	4.77	.544	4.66	4.26	.473
Elaboration & Synthesis	3.88	4.22	.462	**4.49**	**5.39**	**.019**
Average	4.04	4.28	.601	4.34	4.76	.274
Score	58.89	61.11	.770	62.22	65.00	.723

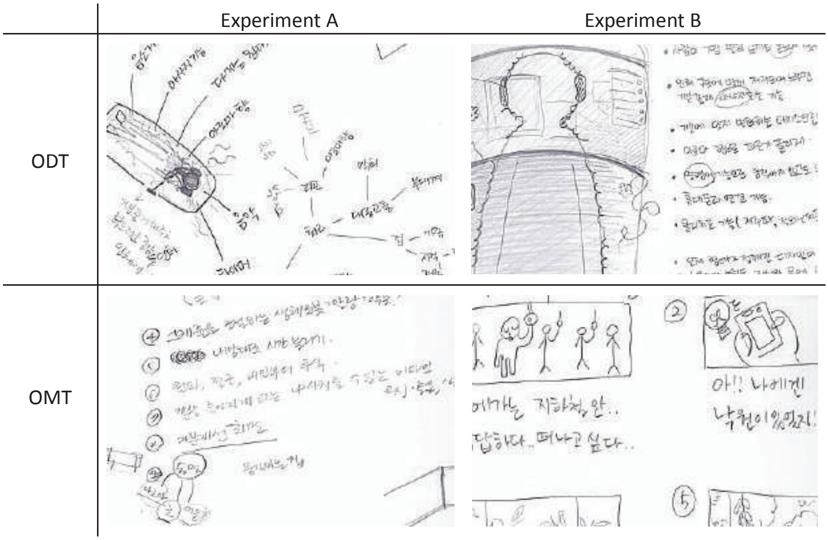

Figure 3. Examples of output in homogeneous groups

Table 4. The evaluation of output creativity (heterogeneous groups)

	Experiment A			Experiment B		
	EDT	EMT	P-value	EDT	EMT	P-value
Novelty	3.39	3.46	.917	2.86	3.34	.191
Resolution	3.39	3.46	.903	**3.59**	**5.32**	**.000**
Elaboration & Synthesis	3.71	3.26	.223	4.22	4.14	.770
Average	3.80	3.69	.815	**3.54**	**4.27**	**.009**
Score	53.00	51.11	.851	**44.33**	**61.11**	**.029**

	Experiment A	Experiment B
EDT		
EMT		

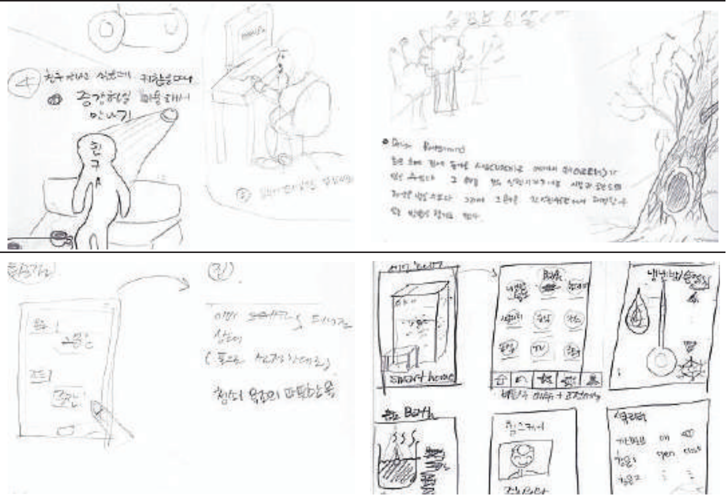

Figure 4. Examples of output in heterogeneous groups

We therefore examined the reason for these differences shown between the design-only teams and multidisciplinary teams in the heterogeneous groups of experiment B (in-depth discussion) by performing a transcript analysis of the creative process. To do so, we transcribed the recorded conversations of the participants and then performed an in-depth analysis by using Nvivo9, a tool for qualitative study of the problem-solving approach and group activity process.

Coding scheme for group creative process

Problem-solving approach

In order to examine which components the participants placed interest in approaching the problem to do the design task, we divided their communication details according to the categories presented in Table 5. This allowed us to know which design characteristics the participants focused on to solve the problem (Jin and Kim 2006, p. 112).

Table5. Coding scheme for the problem solving approach

Code		Explanation	Example
Form Visual factor	Overall Shape	Main object, Size, Color	There are lots of round objects.
	Component Shape	Unit	Speaker, Lamp
Function	General Feature	Common function, Usage	Give emotional security
	Technical Feature	Explicit function, Operation	To drill a hole
Context	External Knowledge	User social context	Get off work
Human	Physical Elements	Body elements, Human Moving, Gestures	Sit, Dip her feet in water
	Mental Elements	Feeling, Responses	Boring, Sad
Designer	Intent	Domain knowledge, Designer's Judgment, Process management	What do workers want? I think it needs a light.

Group activity process

In order to examine the structure of the discourse showing the group work process, the activity process of the group was divided according to the categories presented in Table 6. In their on-site study of group activity, Olson et al. (1992) made 10 observations of software design problem solving meetings that were a part of a small group project. They discovered that the design meeting activity can be classified into 10 categories: 'issue, alternative, criterion, clarification, summary, walkthrough, goal, project management, meeting management, digression, and other.' Rosalie & Jerry (2008) developed this further and differentiated design team communication into three stages: 'design, review & summary, and coordination.' In the present study, we wanted to examine in detail the process of presenting an idea and resolving the design-related demands and issues. We thus divided the process into categories of 'issue, alternative, and criterion.' Also, since in this study there is already a given topic in the task, the 'issue' was further divided into 'task' and 'new topic.' The 'task' is the communication that takes into account the elements '7 PM in the evening,' 'after work,' and 'make feel better' included in the topic**;** 'new topic' is a new problem that needs to be considered in the design task outside the topic given in the task.

Table 6. Coding scheme for the group activity process

Code		Explanation	Example
Issue	Task	Considering the questions for given tasks	What makes us happy?
	New Topic	The major questions, problems, or aspects of the designed object itself that need to be addressed.	Shall we offer this capability to the user?
Alternative		Solutions or proposals about aspects of the designed object. The elaboration of the idea, ways to implement the features decided.	A function to auto-play according to their mood.
Criterion		The reasons, arguments, or opinions that evaluate an alternative solution or proposal.	I think it's an impossible idea because we have to make tangible products.
Review and Summary		Reviews of the state of the design or implementation to date, restating issues, alternatives, and criteria. Clarification and walkthrough.	As I make a list of what we discussed on functions and services.
Management		Project management or meeting management.	Let's finish talking about this idea in 10minutes.
Other		Time not categorizable in any of the previous categories. It's not related to their work.	I'm hungry.

Communication analysis results

Problem-Solving Approach

The codes that showed significant differences between the EDT and EMT were the problem-solving approach, component shape, general feature, external knowledge, and design intent, as presented in Table 7. For all codes other than designer intent, the number of related conversations was greater in the EMT, and among them, external knowledge showed the greatest difference. In other words, the EDT placed a greater weight on the inner knowledge and judgment of the designers during the process of deepening the design, whereas the EMT showed more interest in the knowledge (social relationships, circumstances, design problems) brought from the outside.

The EMT focused on general features and contexts while the EDT placed more weight on designers in the proportion of each code in the conversations regarding the problem-solving approach of a group compared between the EDT and EMT.

Table 7. Comparing the conversations relate to the problem-solving approach between the EDT and EMT

		Number			Proportion	
		EDT	EMT	P-value	EDT	EMT
[Problem Solving Approach]		134	263	**0.012**	1.00	1.00
Form Visual Factor	Overall Shape	8	11	0.260	0.06	0.04
	Component Shape	28	**66**	**0.021**	0.21	0.25
Function	General Feature	38	**103**	**0.004**	0.28	0.39
	Technical Feature	23	28	0.321	0.17	0.11
Context	External Knowledge	16	**50**	**0.001**	0.12	0.19
Human	Physical Elements	0	5	0.060	0.00	0.02
	Mental Elements	5	11	0.132	0.04	0.04
Designer	Intent	**22**	6	**0.044**	0.16	0.02

Figure 5 shows the comparison between the participation rates of design majors and multidisciplinary majors within their own groups in the conversations for each code of the problem-solving approach. The multidisciplinary students showed relatively uniform participation in each code, while the design-only students tended to concentrate on particular codes (component shape, mental element, designer). Those which showed clear differences in the number of conversations were codes leaning greatly on the internal knowledge or judgment of designers.

Table 8. Comparing the conversations relate to the problem-solving approach between design majors in EDT and multidisciplinary majors in EMT

		Number			Proportion	
		Design Majors	Multidis-ciplinary Majors	P-value	Design Majors	Multidis-ciplinary Majors
[Problem Solving Approach]		70	86	**0.338**	1.00	1.00
Form Visual Factor	Overall Shape	2	2	0.500	0.25	0.18
	Component Shape	20	23	0.419	0.71	0.35
Function	General Feature	16	**37**	**0.017**	0.42	0.36
	Technical Feature	12	6	0.236	0.52	0.21
Context	External Knowledge	6	**17**	**0.033**	0.38	0.34
Human	Physical Elements	0	1	0.157	x	0.20
	Mental Elements	5	2	0.209	1.00	0.18
Designer	Intent	14	3	0.101	0.64	0.50

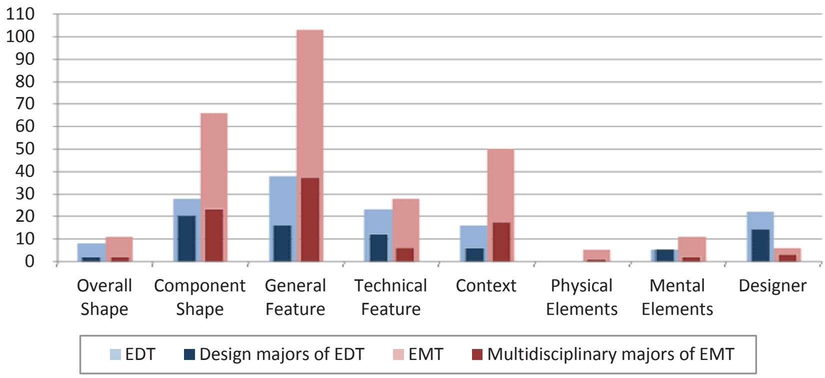

Figure 5. Comparing the conversations relate to the problem-solving approach between design majors in EDT and multidisciplinary majors in EMT

Group Activity Process

The codes which showed significant differences in the number of conversations on the group activity process between the EDT and the EMT are group activity process, alternative, review & summary, with the EMT having more conversations on all three codes. The EMT also had a greater number of conversations in the group activity process code measured by the overall number of conversations. The reason for this is that the EMT participated in much greater number of idea generation (2.8 times) and review & summary (2.4 times) than the EDT.

In terms of the proportion of each code in group conversations, the EMT placed more weight, as is the case with the number of conversations, on alternative and review & summary. Meanwhile, the biggest difference in weight was shown for the code 'other,' which the EDT emphasized. In other words, compared to the EMT, the EDT placed relatively more weight on idle talk than on engaging in new idea generation.

Table 9. Comparing the conversations relate to the group activity process between the EDT and EMT

		Number			Proportion	
		EDT	EMT	P-value	EDT	EMT
[Group Activity Process]		309	**570**	**0.008**	1.00	1.00
Issue	Task	12	5	0.091	0.04	0.01
	New Topic	6	7	0.440	0.02	0.01
Alternative		70	**193**	**0.002**	0.23	0.34
Criterion		34	38	0.360	0.11	0.07
Review & Summary		109	**269**	**0.003**	0.35	0.47
Management		45	58	0.202	0.15	0.10
Other		55	15	0.080	0.18	0.03

Of the conversations on the group activity process, for most codes, the multidisciplinary students showed about 10% more than the design-only students, and large differences were shown only in task and new topic. However, since the number of conversations falling under these two codes was small, and the numerical differences of 0 and 5 each were slight, it is difficult to consider these to have a substantial impact on the group design process. Hence although the weight of conversations within their group by design-only students took up about half and was generally greater than that of the multidisciplinary students, there were no differences concentrated on specific codes.

Table 10. Comparing the conversations relate to the group activity process between design majors in EDT and multidisciplinary majors in EMT

		Number			Proportion	
		Design Majors	Multidiscipli-nary Majors	P-value	Design Majors	Multidiscipli -nary Majors
[Group Activity Process]		150	**221**	**0.058**	0.49	0.39
Issue	Task	4	4	0.500	0.33	0.80
	New Topic	6	1	0.229	1.00	0.14
Alternative		32	64	0.137	0.46	0.33
Criterion		17	16	0.423	0.50	0.42
Review & Summary		55	110	0.056	0.50	0.41
Management		24	24	0.500	0.53	0.41
Other		29	7	0.203	0.53	0.47

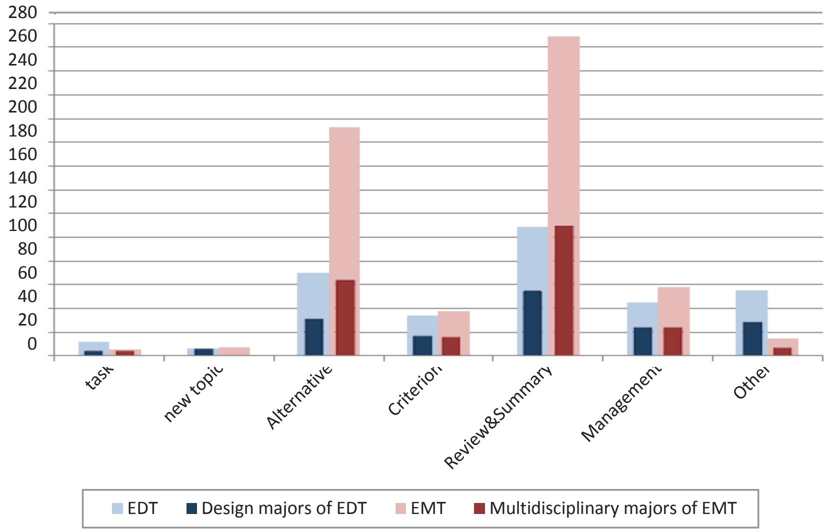

Figure 6. Comparing the conversations relate to the group activity process between design majors in EDT and multidisciplinary majors in EMT

Conclusion

In this study, we examined how the creative process changes depending on the multidisciplinary design knowledge of the group members, i.e., the person creativity element, as well as consider the creativity of the output.

When it is heterogeneous, an multidisciplinary design team with experience of doing projects as a team formed with diverse departments and of taking multidisciplinary courses linked with other departments produced more creative products than a design-only team. Also, although the difference was small at the initial stage of brainstorming over a short time period, a clear difference was shown in the in-depth discussion stage where ideas were further developed over a longer time. Hence we compared the creative process of the design-only teams and the multidisciplinary teams by performing a communication analysis in the in-depth discussion stage of the heterogeneous groups which showed a clear difference in output creativity.

Firstly, the number of conversations on the problem-solving approach and group activity process was about double for the EMT, agreeing with the characteristic that high-performing teams are more verbose (Rosalie and Jerry 2008, p.64).

Secondly, the weights of the conversations by design-only students and multidisciplinary students in each team showed that the latter (about 1/3) participated in the conversations at a ratio for commenting more equally than the design-only students (about 1/2).

Thirdly, in conversations on the problem-solving approach, the EDT placed greater weight on the internal knowledge and judgment of designers, whereas the EMT focused more on outside knowledge and general function. The design-only students tended to concentrate on particular content, especially giving much weight to designer intent. The multidisciplinary students considered much more diverse aspects of design content. According to Chakrabarti and Bligh (1996), generating a wide range of concepts is important, so that valuable concepts are not overlooked. If designers can develop promising concepts, this should increase the possibility of creating better products. Hence it can be said that the possibility is higher for the multidisciplinary students in the heterogeneous groups, who considered design contents from more diverse aspects, to produce better outputs than the design-only students.

Fourthly, Analysis of conversations on the group activity process showed that the EMT actively engaged in idea generation and review & summary. This difference was similarly found when the conversations between the design-only majors and multidisciplinary design majors within each team were analyzed. The EMT characteristic, an active review & summary, was the same high design performing team's in study of Rosalie and Jerry (2008, p.63). Their study has shown that in the high performing teams, typically a member sifted through the team's communications in order to summarize discussion content on a given topic. The summaries provided a structuring mechanism that organized the team's work and progress-to-date on a topic. Summaries also served a "check and balance function," as members made certain their ideas were included and accurately represented. In severe contrast, summary comments were either almost non-existent or only recapped a single individual's input in the low performing teams.

As such, we were able to confirm that students who received multidisciplinary design education, when they form a team with various other majors to do a project, show more creative output and solve problems with a different creative process than students majoring in design only.

Limitations and future research

We recognize several limitations in this study. First, this research would need to be based on a much broader statistical range. The conclusion may therefore only have hypothetical status. This research helped build up several hypotheses. We would need further studies on one of the hypotheses that the heterogeneous team, including design-only major place greater weight on the internal knowledge, whereas the heterogeneous teams including multidisciplinary design major focus more on the outside knowledge on the problem-solving approach with more participants.

Secondly, the current study treated knowledge of individual level, group diversity of team level and design field. The individual character of group members is factored out to the largest extent since we focused on how to use knowledge in problem solving to confirm the effect of multidisciplinary design education. In the future study, we'd like to take a look at cognitive styles in the study hereafter, as the styles seem to be another possible element in individual levels associated with individual knowledge on which multidisciplinary education can have an impact.

Lastly, a limitation to consider is in the introduction of design group members into a study focused on academic settings. Jeffries(2011) suggests academics differ to practitioners in their conception of skills relevant to creativity within a specific design related subject. We need to study creative performances of participants after being practitioners in organizations to explore multidisciplinary design education effects from practical work environments.

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