JFMSE, 27(6), pp. 1880~1890, 2015.
수산해양교육연구, 제27권 제6호, 통권78호, 2015.
www.ksfme.or.kr
http://dx.doi.org/10.13000/JFMSE.2015.27.6.1880

Development of the 'convergence motive' scale for interdisciplinary knowledge fusion

Sung-Mi PARK† · Hwang-Kyu YANG
(Dongseo University)

다학제간 지식융합을 위한 '융합동기' 척도 개발 연구

박성미† · 양황규
(동서대학교)

Abstract

The purpose of this study was to development of the 'convergence motive' scale for interdisciplinary knowledge fusion. Based on results from literature review, this study clarifies a theoretical ground for 'convergence motive'. Initial items to measure this concept were verified by content analysis and then finalized. After a pilot test done with 568 college students, gathered data were analyzed by item selection and exploratory factor analysis to verify their validity. Next, the main test implemented with 1,211 college students was analyzed with exploratory factor analysis using the method for rotation based on maximum likelihood analysis and direct oblimin for validating the final items to measure 'convergence motive'. As a result, the scale for 'convergence motive' consists of 43 items to measure the following four factors: collaboration to identifying and solving problems, challenge of a new perspective, communication for convergence, cohesion for convergence. Construct validity and criterion-related validity were performed at last to check this scale's theoretical construct. In conclusion, this study concluded that the scales for convergence motive could be generalized and applicable to other samples.

Key words : Knowledge fusion, Convergence motive, Scale, Interdisciplinary

Ⅰ. Introduction

It is common that any academic discipline cannot be existed alone without other disciplines. Many academic disciplines, such as engineering and economics, humanities and natural sciences, psychology and political science, exchange simple information and develop further into knowledge convergence. This tendency becomes a background for the convergence education (Park, 2014; Oh, et al., 2012). Considering contemporary society changing rapidly, separate discipline would not provide enough explanation for various needs of human kinds (Min, Lee, & Chae, 2005; Park, 2013).

As changing into the knowledge-based society, a demand for convergence capability, especially knowledge fusion in engineering becomes significant(Besselaar & Heimeriks, 2001; Frodeman, 2010; Kane, 2003; Oksen, Magid, & de Neergaard, 2009). Knowledge fusion in engineering is worth to combine knowledge from various disciplines and

† Corresponding author : 051-320-1866, psm1994@dongseo.ac.kr

create the advanced way of problem solving(Kane, 2003; Oksen et al., 2009; Schiebinger & Schraudner, 2011). As a result, from the engineering field, the multidisciplinary or interdisciplinary convergence study has actively performed to combine applied science and social phenomenon and to develop creative ideas and innovations(Park, 2013; Bhavnani & Aldridge, 2000; Korres & Tsami, 2010).

However, simple combination among different disciplines would not lead to a creative and worthy problem-solving. Knowledge fusion becomes possible with convergence motive which inter-connect and combine different knowledge from various disciplines and find a solution for unsolved problems in a mediating space, that is, a trading zone(Oh, et al., 2012; Gorman, 2010; Sharon & Keiichi, 2009).

Convergence motive has been partially explained in previous studies on group creativity(Kwon & Jang, 2013; Shalley & Gilson, 2004) and collective intelligence(Oh, 2010; Ocker & Fjermestad, 2008).

According to those literatures, convergence motive can be explained in terms of process and outcome.

First, in terms of process, it is regarded as an encouragement for revitalizing individual way of knowing and perceiving. Intellectual curiosity on convergence, interest in problem-finding and problem-solving, task-oriented commitment to solving problem by merging and synchronizing different disciplines explain convergence motive(Oh, et al., 2012). Similarly, Kwon and Jang(2013) explain convergence motive in terms of group creativity, insisting that a creative result is dependent on convergence motive as an encouragement to participate in the task positively.

Second, convergence motive is defined as an outcome of shared intelligence. Siau(1995) explains convergence motive as an idea or an implication for a new method for problem solving. In addition, Jay(1984) defines convergence motive as a new way of problem solving in order to improve the current situation. It means that convergence motive pursues a synthetic thinking for identifying, planning and realizing a new idea, rather than persisting one discipline's unique way of finding a solution.

To be summarized, convergence motive is a drive for the individual to recognizing and solving a problem by merging different disciplines as well as a new system to combine various disciplinary methods for solving problems.

In fact, few studies reveal that convergence motive is related with creativity and creative problem-solving(Oh, et al., 2012; Rotberg, 2010; Shalley & Gilson, 2004). They tell that convergence motive is significant as a mediator of creating knowledge convergence among various disciplines. However, convergence motive as a mediator of knowledge fusion has not concisely studied theoretically and empirically.

This study investigates a theoretical ground for the concept of convergence motive as a trading zone for knowledge fusion in the engineering field and concurrently develops its measuring scale. Research questions for this study are set as follows. First, which variables constitute convergence motive as a trading zone for knowledge fusion, and what items could measure these variables? Second, is it possible to generalize these variables? Third, could criterion validity of these variables be validated?

Ⅱ. Developing items for measuring convergence motive

1. Developing initial items

Previous literatures on convergence motive indicate that convergence motive consists of various variables, not a separated, individual concept(Kwon & Jang, 2013; Oh, et al., 2012; Shalley & Gilson, 2004; Siau, 1995).

Convergence motive can be explained as either a process or an outcome. In terms of a process, convergence motive is identified as a curiosity on convergence and an immersion on convergence (task-oriented focus). It can also be explained as a suggestion of new idea for solving problems and an academic way of problem solving. To be specific, a curiosity on convergence is a creative tendency to accept new knowledge, perspective and opinion with intellectual curiosity. The immersion on convergence is a willingness to learn with inner motive, task-oriented focus on problem-solving. It suggests that convergence motive indicates an internal status to activate and direct the energy for knowledge fusion. A suggestion of new idea for solving problems is convergence oriented in problem-finding and solving, challenging and creating a new thing. And the academic way of problem solving means to pursue the synthetic thinking for identifying, planning and realizing a new concept.

Convergence motive is the system to realize the foundational and significant issue which cannot be solved within the frame of the individual discipline and to combine different methods of various disciplines. As indicated, there is no concrete agreement on the definition of convergence motive, resulting in the use of various similar terms. However, these terms show one definite similarity, that is, to realize the most significant issue which cannot be solved within the frame of the individual discipline and to make a creative solution by combining and exchanging different discipline (Gorman, 2010; Shalley & Gilson, 2004).

To be concluded, these terms share the following five(5) similarities. The first similarity is to share the interest on convergence and to inter-connect through the network(Curiosity on convergence). Second, they share the dispersed cognitive resources(Immersion on convergence). Third, each individual experience a dynamic interaction through collaboration and participation(Communication as a tool for convergence). Fourth, there is a shared mind or vision for problem solving(Challenge to identifying and solving problems). Fifth, it moves freely in the trading zone(context made by members) as a live organism(Cohesion for convergence). Thus, a positive energy for a new way of problem solving can be created through the above five points. Thus, this study developed items to measure convergence motive, focused on the above five(5) similarities.

Preliminary items to measure ‘convergence motive’ were made by the results from literature reviews and Delphi study on convergence(Park, 2014). Convergence motive consists of 8 items on curiosity on convergence, 12 items on immersion on convergence, 10 items on communication as a tool for convergence, 8 items on challenge to identifying and solving problems, and 15 items on cohesion for convergence (<Table 1>).

2. Item Content validity

For verifying content validity, selecting and modifying initial items, eight experts(2 professors with Doctor of Engineering, 2 professors with Doctor of Aesthetics, 2 professor with Doctor of Education, and 2 professors with Doctor of

<Table 1> The item content validity of the scale for convergence motive

Factors		Explanation	# of initial items	# of deleted items	# of revised items	# of added items	# of final items
Process	Curiosity on convergence (Oh et al., 2012; Kwon & Jang, 2013)	Creative tendency to accept new knowledge, perspective and opinion with intellectual curiosity	10	2	1		8
Process	Immersion on convergence (Oh, et al., 2012)	Willingness to learn with inner motive, task-oriented focus on problem-solving	12	2		1	12
Process	Communication as a tool for convergence (Kwon & Jang, 2013; Siau, 1995)	Communication based on collaboration, and a basic unit for knowledge fusion	12	2	1		10
Outcome	Challenge to identifying and solving problems (Oh, et al., 2012)	Tendency oriented to identify and solve problems; continuous challenge to new things	10	2	2		8
Outcome	Cohesion for convergence (Sharon & Keichii, 2009)	Collective climate for convergence, decision-making for logical negotiation	12		1	3	15
Total			56	8	5	4	53

Humanities) evaluated content validity and similarity of items for measuring 'convergence motive'. Each item was rated either yes or no (2-point scale), and items which seemed awkward or irrelevant to variables were revised or deleted. New items were added by the experts' opinions. As a result, 8 items with low validity were finally deleted. 5 items were revised, and 4 new items were added.

Ⅲ. Research Method

1. Subject and Research procedures

The purpose of this study was to development of the 'convergence motive' scale for interdisciplinary knowledge fusion. The followings are the research process and subject.

First, the initial items (56 items) to confirm the variables for measuring convergence motive were selected by literature reviews, and the content validity was verified (53 items). Second, in order to verify the initial items empirically, the pilot test was conducted for two weeks in May, 2014, with sophomores and seniors of the college in P city. Results from 568 students were collected and analyzed. The item selection process was conducted, followed by the principal component analysis, in order to decide the final items (50 items in total). Third, the main test was performed with college students in P city, K city, D city, G city and S city, throughout the country, using the items finalized by the pilot test, for 4 weeks in October, 2014. Answers from 1,211 students (307 from Aesthetics/Design discipline, 295 from Social Science, 312 from Engineering, and 297 from Natural Sciences) were collected with a rate of 81.14%, and they were analyzed by the item selection process and the principal component analysis so that the final 43 items were confirmed to measure convergence motive. Fourth, for the purpose of checking validity and stability, construct validity and criterion-related validity were confirmed.

2. Scale

In this study, 'convergence thinking' as a trading zone for knowledge fusion was measures in order to confirm criterion-related validity of 'convergence motive' as a mediator for knowledge convergence. Convergence thinking is a new thinking system to integrate different disciplinary methods for solving problems, showing an important mediator for multidisciplinary convergence (Park, 2014). The scale for 'convergence thinking,' developed by Park (2014), consisted of 5 factors, 52 items. Details are as follows. First, synthetic thinking consists of 11 items (α=.88), measuring an ability to review new knowledge by using memory, thought, pursuit to new possibility based on divergent thinking. Second, objective information usage consists of 11 items (α=.88), measuring recognition on the object, collection and processing of objective information, and rule of thumb based on objective data. Third, logical thinking measures the step-by-step problem solving, perfect logics by principles, consistent and predictable products, consisting of 10 items (α=.87). Fourth, intuitive thinking consists of 12 items (α=.87), measuring the sixth sense or intuition by subjective thinking, peculiar but irrational perspective, and an ability to create perfection by momentary insight. Fifth, subjective thinking consists of 8 items (α=.87), measuring understanding on human nature and unconsciousness, and image on inner world of the humans.

3. Data analysis

Collected data were analyzed by following methods. First, data collected in the pilot test were checked with item-total score correlation analysis and the exploratory factor analysis. Second, data collected in the main test went through item selection (item-total score correlation analysis), exploratory factor analysis using the method for rotation based on maximum likelihood analysis and direct oblimin as the same procedure in the pilot test. Third, for generalizing the items of convergence motive finalized in this study, confirmatory factor analysis was performed to check construct validity as well as correlation analysis with the scale for 'convergence thinking' to check criterion-related validity, by using AMOS 18.0(Arbuckle, 2009).

Ⅳ. Results

1. Item analysis on data from the pilot test

To determine the validity of the scale of 'convergence motive' (53 items), average score, item-total score correlation, and theoretical adequacy of each item became the standard of judgment.

Items of which average score are above 4.5 or below 2.5 were determined skewed and less distinctive, but no items showed such results. Items with item-total score correlation of below .30 were determined not to be able to measure the same psychological properties. And items above .70 showed extremely high level of correlation, appearing less distinctive. No items showed below .30 or above .70 of item-total score correlation.

The principal component analysis was performed to check factors of the scale of 'convergence motive' (53 items). To determine the number of factors, Cattell's scree analysis results, factor comprehensibility, Eigenvalue, and cumulated variance percentage were applied. At last, four factors were confirmed to construct convergence

motive. Correlation between factors was checked to determine the factor rotation method. In the final factor structure produced by oblique rotation, items not included in the designated factors, items' factor loading less than .30, or items with extremely high level of factor loading were reviewed.

As a result, three items with below .30 of factor loading were deleted in the scale of 'convergence motive.' Though unique variance could not be ruled out completely in the exploratory factor analysis, the principal component analysis was performed to extract latent variables which became a reason for between-variables correlation. As stated above, scree analysis, comprehensibility, and cumulated variance percentage were applied along with oblimin rotation. Item-total score correlation of each factor was performed, and no item showed less than .30 of item-total score correlation. Finally, the scale of 'convergence motive' consisted of 50 items in four factors; in details, 15 items measuring factor 1, 13 items in factor 2, 10 items in factor 3, 12 items in factor 4.

2. Item analysis on data from the main test

In Order to obtain the verification value of KMO(Kasier Meyer Olkin) and Bartlett, and verified whether the data would be suitable for the factor analysis, got the factor structure matrix through maximum likelihood and direct oblimin rotaion(<Table 2>).

<Table 2> KMO & Bartlett's test

KMO(Kaiser-Meyer-Olkin)		.946
Bartlett's test	$\chi 2$	11952.733
	df	1035
	p value	.000

According to results of the main test analysis, no items showed its average score of above 4.5 or below 2.5, nor its item-total score correlation of less than .30. But, the standard deviation of c22 item appeared above 1.0, so deleted one item. The determined items were divided into four factors, as the pilot test analyzed, and oblique rotation was performed. Factor loading was above .30 in the final factor structure. But, the factor loading of c5, c21, c24, c26, c32 items appeared below .30, so deleted six items (43 items).

<Table 3> showed factor matrix and variance of four factors of the scale of 'convergence motive.' According <Table 2>, the total amount of variance accounted for factors was 42.484%. The amount of variance accounted for factor 1 was 30.988%, factor 2 with 5.388%, factor 3 with 3.563%, factor 4 with 2.545%.

Factor 1 consisted of 14 items(c50, c49, c48, c46, c40, c47, c38, c41, c39, c37, c36, c43, c44, c45), explaining recognition on the shared goal, information sharing and knowledge management, communication for collaboration, and rational decision-making in a process of collaboration as the base for convergence. Factor 1 was named as 'Collaboration to identifying and solving problems.'

Factor 2 consisted of 10 items(c30, c29, c34, c31, c35, c23, c28, c25, c42, c33) included brainstorming activity in a collaborative relationship and creative tendency and attitude. Factor 2 was named as 'Challenge of a new perspective,' explaining pursuit to new things, a different way of problem-solving, attempt of difficult but different solutions, social patience for performing tasks, prioritizing and effective processing of given tasks, and a focus on achieving the common goal, creative problem-solving by inner motive.

Factor 3 consisted of 11 items(c15, c14, c16,

c17, c12, c11, c13, c09, c18, c20, c19), including sophisticated interpersonal skills to communication flawless communication with people whose perspectives and interests were different, and

<Table 3> Factor matrix of convergence motive scale

Items	F1	F2	F3	F4
c50. I respect the group's decision for a creative solution for the common task	.745			
c49. The transparent & rational decision-making is necessary for achieving the common goal.	.736			
c48. Decisions for performing the common task are made by in-depth discussion and objective standards.	.726			
c46. I maintain a collaborative relationship by respecting myself and others, if possible.	.688			
c40. I understand and share the goal of collaboration.	.664			
c47. I communicate and share other's desires and pursue mutual satisfaction.	.662			
c38. I collaborate with others, thinking I can learn from others.	.651			
c41. I communicate different opinions and make valuable decisions, based on trust.	.621			
c39. I take responsibility of the given role, if collaborating.	.606			
c37. I accept other disciplines, recognizing difference in perspectives.	.597			
c36. In case of common task, I share the common goal and vision.	.576			
c43. I exchange and share relevant information and knowledge for performing the common task.	.570			
c44. I try to understand knowledge of other disciplines, in case of collaboration.	.535			
c45. Conflicting thoughts can be solved in a productive way, while performing the common task.	.511			
c30. I use logical and creative thinking to solve problems.		.727		
c29. I have strength to create a new thing, thinking differently.		.698		
c34. I tend to attempt a new way, rather than following the standard way of thinking.		.666		
c31. I try to accept a new knowledge, perspective and opinions outside of the stereotype.		.648		
c35. I try various ways to solve difficult tasks.		.621		
c23. I tend to accept risk and challenge.		.579		
c28. I try a creative problem-solving with exiting knowledge.		.540		
c25. For effective performance, I can reorganize available resources.		.518		
c42. Possible to manage systematically ideas and knowledge created in a process of collaboration.		.505		
c33. I am sensitive to the environment, and tend to adopt well.		.467		
c15. I can deliver a well-defined goal to participants in communication and create their understanding.			.720	
c14. I can mediate differences for the successful negotiation.			.689	
c16. I can use appropriate words and expressions for the purse of info delivering, persuasion, or rapport.			.680	
c17. For achieving the common goal, I focus on the task in an active manner.			.668	
c12. I can communicate with others and expand the area of understanding.			.643	
c11. I can communicate with others and mediate different perspectives and thoughts			.632	
c13. I can create a climate for communication by caring others.			.599	
c09. I can understand differences in opinions for a successful negotiation.			.551	
c18. I tent to become patient and strive for achieving the goal.			.546	
c20. Try to focus and complete the tasks, even though they are forcefully given.			.541	
c19. I am able to focus on the task for a long time and become passionate.			.526	
c02. It is desirable to collaborate with others in a rapidly changing society.				.753
c03. Each person has his unique ability, and collaboration can bring about positive results.				.740
c04. Collaboration is valuable to each other, despite of difference.				.722
c01. It is helpful to share knowledge and professional skills of others.				.585
c06. Difference is unable to learn from each other.				.569
c08. Creative knowledge can be developed by solving problems with various experts.				.550
c10. I try to communicate through open-minded attitude for mediating and solving conflicts.				.531
c07. Individually developed knowledge should be shared with others.				.511
Eigenvalue	13.325	2.317	1.532	1.094
Variance Accounted (%)	30.988	5.388	3.563	2.545
Accumulated Variance (%)	30.988	36.375	39.938	42.484
Number of Item	14	10	11	8
Coefficient	.910	.850	.875	.843

Note: F1=Collaboration to identifying and solving problems / F2=Challenge of a new perspective/ F3=Communication for convergence / F4=Cohesion for convergence

and solve conflicts in a collaborative climate, communication based on sharing the goal and

feeling sympathy. Factor 3 was named as 'Communication for convergence,' explaining mature communication.

Factor 4 consisted of 8 items(c02, c03, c04, c01, c06, c08, c10, c07), named as 'Cohesion for convergence.' Factor 4 explained a collaborative relationship to exchange thoughts and to create positive results, including consideration of positive things of collaboration, importance of complementary and its benefits, learning in differences among people's perspectives, creative products through sharing thoughts.

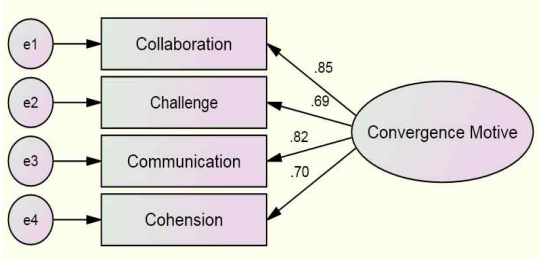
The final items showed satisfactory results in the factor analysis, thus the scale of 'convergence motive' consisted of the final 43 items. Item-total score correlation and Cronbach' α coefficient of items included in the scale of 'convergence motive' appeared in <Table 3>.

Reliability coefficient of the 'convergence motive' scale showed .949. Each factor's reliability coefficient was as follows: factor 1 (collaboration to identifying and solving problems) with .910, factor 2 (challenge of a new perspective) with .850, factor 3 (communication for convergence) with .875, factor 4 (cohesion for convergence) with .843. All results appeared satisfactory.

3. Verify Validity

3.1 Construct validity

For confirming variables of the scale of 'convergence motive' theoretically, the model was designed and analyzed by confirmatory factory analysis by AMOS 18.0(Arbuckle, 2009). In this model, each variable were loaded, and correlation only existed between factors, not residuals. $\chi 2$, NFI, IFI, CFI, RMSEA were used as goodness-of-fit index, and maximum likelihood was applied. [Fig. 1] showed the estimated model, and its fit index showed goodness($\chi 2$ = 58.797(df=2), NFI=.943, IFI=.944, CFI=.944, RMSEA=.042).



Note: collaboration=collaboration to identifying and solving problems/challenge=challenge of a new perspective/ communication=communication for convergence/ cohesion=cohesion for convergence

[Fig. 1] Construct Validity(n=1,211)

This result means that the model specification of 'convergence motive' with four factors could be standardized. In addition, the theoretical hypothesis of which knowledge convergence came from convergence motive as a trading zone was empirically proved.

3.2 Criterion-related validity

In order to confirm criterion-related validity of 'convergence motive' scale, correlation between factors of 'convergence motive' scale and 'convergence thinking' scale, a trading zone for knowledge convergence, was analyzed. According to Table 4, factors of 'convergence motive' and 'convergence thinking' showed positive correlation, from .668 to .236 (statistical significance in .01).

V. Conclusion and Suggestions

The purpose of this study was to development of the 'convergence motive' scale for interdisciplinary knowledge fusion. Based on the results, this study concluded the followings.

First, the pilot test and the main test were performed to select the final 43 items for the scale of 'convergence motive.' It was constructed by four factors. Exploratory factor analysis showed the factor loadings of each factor; factor 1 (collaboration to identifying and solving problems) with .910, factor 2 (challenge of a new perspective) with .850, factor 3 (communication for convergence) with .875, factor 4 (cohesion for convergence) with .843. The results supported previous studies, including Sharon and Keiichi (2009) which emphasized collaboration as a base for convergence as well as Oh et al. (2014) and Rotberg (2010) which indicated curiosity, interest, and commitment for convergence motive's constructs. Convergence motive explained motivation and collaboration for convergence, which supported studies of Kwon and Jang (2013) on the group's climate and Siau (1995) on focus and commitment to the task. Thus, convergence motive was validated as a mediating variable for knowledge convergence in this study.

Second, in order to check the stability of factors of 'convergence motive,' confirmatory factory analysis was performed. This procedure was necessary to see the possibility of generalizing the structure of 'convergence motive.' As a result, the estimated model showed the goodness of fit, showing the five-factor structure of convergence motive could be standardized. Next, criterion-related validity of 'convergence motive' scale was checked by correlation analysis with factors of 'convergence thinking.' Factors of convergence motive and convergence thinking showed positive correlation, proving criterion-related validity. Therefore, convergence motive scale in this study was theoretically and empirically validated, and further could be standardized.

Based on the above results, limitations and implications of this study are suggested as follows.

First, convergence motive that this study intended to measure has been theoretically discussed in previous convergence-related studies, and now empirically proved in this study. It becomes possible to develop educational programs for convergence or apply convergence motive as a mediator for creative problem-solving.

Second, convergence motive developed in this study could be relevant to variables of idea crossing, intersecting ability, and trading zone. Later, it would be necessary to see correlation among important variables of convergence included

<Table 4> Correlation between factors of convergence thinking and convergence motive

Construct	Factors	①	②	③	④	⑤	⑥	⑦	⑧	⑨
Convergence Thinking	① Synthetic	1								
	② Objective	.607**	1							
	③ Logical	.507**	.641**	1						
	④ Intuitive	.467**	.423**	.366**	1					
	⑤ Subjective	.458**	.489**	.432**	.617**	1				
Convergence Motive	⑥ Collaboration	.461**	.468**	.478**	.446**	.364**	1			
	⑦ Challenge	.579**	.445**	.436**	.447**	.380**	.630**	1		
	⑧ Communication	.391**	.423**	.415**	.312**	.286**	.668**	.577**	1	
	⑨ Cohesion	.324**	.346**	.335**	.311**	.236**	.612**	.365**	.627**	1

Note: ① Synthetic thinking ② Objective thinking ③ Logical thinking ④ Intuitive thinking ⑤ Subjective thinking ⑥ collaboration to identifying and solving problems ⑦ challenge of a new perspective ⑧ communication for convergence ⑨ cohesion for convergence

**=p < . 01

in previous studies. It also would provide fundamental data for convergence study and convergence education.

Third, this study confirmed factors of convergence motive developed by literature review and expert Delphi study. And, items included those factors could be reconstituted as the measurement. Specifically, construct validity and criterion-related validity of convergence motive were confirmed, showing the possibility of standardizing it by the nationwide sampling.

References

Arbuckle, J. L.(2009). *Amos 18 User's Guide.* Chicago: SPSS.

Besselaar, P & Heimeriks, G.(2001). Disciplinary, multidisciplinary, interdisciplinary: Concepts and indicators. *Paper for the 8th conference on Scientometrics and Informetrics.* Sydney. Austrailia.

Bhavnani, S. H. & Aldridge, M. D.(2000). Team work across disciplinary Borders: A bridge between college and the work place. *Journal of Engineering Education*, 13~16.

Choi, Yu-hyun et al.(2012). Development of STEAM curriculum model for cultivating of creative and integrative thinking person. *Korean Journal of Technology and Education,* 12(3), 63~87.

Cross, N. G.(1990). The nature and nature of the design ability. *Design Studies,* 11(3), 127~140.

Frodeman, R.(2010). *The Oxford Handbook of Interdisciplinarity.* NY: Oxford University Press.

Gorman, M.(2010). *Trading zones and interactional expertise: creating new kinds of collaboration.* Cambridge, London: MIT Press.

Jay, D.(1984). *Unpublished Theory of Design Lecture Note.* Institute of Design, IIT.

Jeong, Young-Ki(2012). A study on convergence case in Philosophy and Engineering centered on good engineering. *Studies in Philosophy East-West,* 63, 271~291.

Johansson, F.(2004). *The Medici effect: Breakthrough insight at the intersection of ideas, concepts, and cultures*. Harvard Business School publishing corporation.

Kane, S. A. (2003). Interdisciplinary Faculty Development Seminars A Model for Learning Emerging Technologies While Developing Interdisciplinary Partnerships. *Journal of Science Education and Technology,* 12(4), 421~430.

Kang, Jung Ha & Choe, In Soo(2006). Effects of Creative Problem Solving Program through Generating Product. *Journal of Educational Psychology,* 20(3), 379~701.

Kim, Jeong-hyo(2012). Exploring the possibility of Interdisciplinary education for convergence education in knowledge-based society. *Korean Journal of Culture and Arts Education Studies,* 7(1), 175~200.

Kim, Min Jeong(2012). A Study on the Interdisciplinary Integrated General Education Curriculum in the University of Science and Technology. *Journal of General Education, 6(3),* 357~381.

Kim, Seung In & Jun, Soo Jung(2013). The Development of Convergence Design Education Process. *Journal of Digital Design, 13(2),* 127~136.

Kim, Yoo-shin, Yoon Sang-Keun, & Ahn, Ho-Young(2012). Consilince of Engineering Refinements and Liberal Arts Education. *Journal of Fisheries and Marine Sciences Education,* 24(2), 346~354.

Korres, K. & Tsami, E.(2010). Supporting the development of critical thinking skills in secondary education through the use of interdisciplinary statistics' and mathematics' problems. *Journal of Interdisciplinary Mathematics,* 13(5), 491~507.

Kwag, Eun-Hye & Lee, Eun Kyung(2011). Kierkegaard's Subjective Knowledge and its implication to Moral Education. *Journal of Moral Education,* 23(1), 153~182.

Kwon, D. & Jang, S.(2013). The Effect of Multidisciplinary Design Education for a Creative Climate in the Collaborative Design Process. *Archives of Design Research,* 26(3), 241~261.

Lee, Kwangwoo & Oh, Eun Soon(2012). A study on the perception of curriculum for cultivating students' creativity in secondary school. *Journal of Curriculum Integration,* 6(1), 45~68.

Lee, Daehyun(2008). A study on the history of intuition research and its mathematics educational implication. *Journal of the Korean school mathematics,* 11(3), 363~376.

Lee, Jeong-yeol & Rhi, Joo-myung(2010). Meaning of design thinking. *Proceedings of Korean Society of Design Science,* 10, 62~63.

Lee, Ji-sun & Eune, Ju-hyun(2009). Design thinking adaptation for creative emergence in technology industry. *Journal of Digital Design,* 9(4), 344~352.

Leong, B. D. & Clark, H.(2003). Culture-Based knowledge: Towards New Design Thinking and Practice – A Dialogue. *Design Issues,* 19(3), 48~58.

Min, Kyungwoo, Lee, Soonjong, & Chae, Sungzin(2005). Development of Interdisciplinary design education in Korea. *Proceedings of Korean Society of Design Science,* 5, 226~227.

Oh, Jung Suk(2010). A Delphi Study of Developing Communication Competencies for Undergraduate Students. *Journal of Educational Technology,* 26(2), 241~266.

Oh, Hunseok, Kim, Heejung, Bae, Hyongjun, Seo, Dongin, & Kim, Hansol(2012). What drives convergence? *Journal of research in education,* 43, 51~82.

Ocker, R. J. & Fjermestad, J.(2008). Communication differences in virtual design teams: findings from a multi-method analysis of high and low performing experimental teams. *ACM SIGMIS Database*, 39(1), 51~67.

Oksen, P.・Magid, J.・de Neergaard, A.(2009). Thinking Outside the Box: Interdisciplinary Integration of Teaching and Research on an Environment and Development Study Programme. *Interdisciplinary science reviews. 34(4).* 309~326.

Park, Sung-mi(2013). Analysis on the convergence for knowledge fusion in the field of the engineering, science, aesthetics, humanities, and social sciences. *Journal of Fisheries and Marine Sciences Education,* 25(5), 1031~1045.

Park, Sung-mi(2014). *Analysis of Design Thinking and Creativity through Multidisciplinary Education in Engineering.* National Research Foundation, Research reports.

Ro, Sangwoo & An, Dongsun(2012). A study on the theoretical-practical changes of present education in view of the academic convergence. *Journal of Educational Research,* 10(1), 67~88.

Rotberg, R. I.(2010). Biography and Historiography: Mutual Evidentiary and Interdisciplinary Considerations. J*ournal of Interdisciplinary History,* 40(3), 305~324.

Schiebinger, L. & Schraudner, M.(2011). Interdisciplinary Approaches to Achieving Gendered Innovations in Science, Medicine, and Engineering. *Interdisciplinary Science Reviews,* 36(2), 154~167.

Shalley, C. E. & Gilson, L. L.(2004). What leaders need to know: A review of social and contextual factors that can foster or hinder creativity. *The Leadership Quarterly,* 15(1), 33~53.

Sharon, H. P. & Keiichi, S.(2009). *Design Integrations: Research and Collaboration.* Translated in Korea by Jeong & Kim(2011). Design Integrations. Paju: Angrapix.

Siau, K. L.(1995). Group creativity and technology. *The Journal of Creative Behavior,* 29(3), 201~216.

Teal, R.(2010). Developing a (Non linear) Practice of Design Thinking. *International Journal of ART and Design Education,* 29(3), 294~302.

Yun, Ho-chang(2004). Concerning the Subjective and Objective Math. *Proceedings of the Korea Institute of Psychiatry,* 20, 47~57.

• Received : 24 September, 2015
• Revised : 06 October, 2015
• Accepted : 13 October, 2015