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CROSS-DISCIPLINARY KNOWLEDGE: DESPERATE CALL FROM BUSINESS ENTERPRISES IN COMING SMART WORKING ERA

Jungwoo LEE

Yonsei University, Yonsei Ro 50, Sudaemun Gu, 120-749 Seoul, Republic of Korea

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Abstract. Science and technology is critical for execution and operations of modern businesses. As business operations consists of purposeful execution of technologies with appropriate social cooperation and coordination, knowledge in use is actually cross-disciplinary irrespective of domain or discipline of business. As information technology infiltrates today's businesses, people would need to work smarter using technologies including information technologies. This study explores executives' perceptions of cross-disciplinary knowledge in coming era of smart businesses. An instrument was developed, asking questions about relative weights of different cross-disciplinary knowledge, frequencies and necessity of cross-disciplinary training, decision criteria in recruiting new employees and in promoting existing employees, and preferences in cross-disciplinary curriculum and sequence of relevant training courses. Results indicate that executives maintain high opinions concerning the value of science and technology as a critical contributor to the successful cross-disciplinary operation of their businesses. They seem to understand clearly that science and technology may not benefit their businesses unless it is applied in a cross-disciplinary manner. Executives prioritize cross-disciplinary knowledge domains as follows in order of importance: (1) Science Technology Enterprise (STE); (2) Science Technology Society (STS); and (3) Science Technology Humanities (STH). Implications are discussed with further research issues.

Keywords: science technology society, science technology enterprises, science technology business, science technology humanities, business enterprise, executives' assessment, inter-disciplinary knowledge, cross-disciplinary knowledge, smart working era, smart work, information technologies.

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Corresponding author Jungwoo Lee
E-mail: *jlee@yonsei.ac.kr*

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Introduction

Advancement of science and technology, in effect, underlies today's industrialized society with so many business enterprises based on these advancements, especially since the Industrial Revolution. The Industrial Revolution was the period when science and technology was actually begun to put into use by applying it to practices and businesses, with these applications bringing about tremendous changes in our society (Leydesdorff 2012). Based on such changes, capitalism has evolved into the world of business corporations of mass production and business management. Hence, the source of wealth behind contemporary society is based on the development and use of science and technology by business enterprises.

In this century, there have been many studies concerning the processes through which science and technology advances or of where and how they exert influences (Pinch, Bijker 1984; Bijker *et al.* 1987). In this context, science, technology society (STS) emerged as an academic discipline, though the emergence of STS is relatively recent as compared to the history of science and technology itself (Osborne *et al.* 2003; Borup *et al.* 2006). STS is a cross-disciplinary discipline which is based on the perception that science and technology have the same historical root as humanities and social sciences and that the interaction and convergence of these areas are getting more important when we are facing the current reality of increasing specialization and detachment (Gregory 2007).

However, an analysis of STS-related studies shows that STS can be characterized as a discipline combining different research trends rather than as a clearly-defined independent field of science (Yager 2000; Simmons et al. 2005; Zeidler *et al.* 2005; Wajcman 2006). Such trends in research of STS are also reflected in education, and many studies have been conducted on the organization and improvement of curricula in education under the name of STS. In particular, since the 1980s, STS has been a globally-recognized discipline in secondary education (Yager 2000, 2007; Sjøberg 2001; Aikenhead 2003; Brickhouse, Kittleson 2006; Mansour 2009). STS studies in educational contexts investigate how the development of STS curricula mainly in middle and high schools has changed the way teachers and students perceive science and technology. In this context, several studies have made progressive attempts to develop and refine instruments to measure perceptions concerning science and technology (Sjøberg 2001; Lee, Erdogan 2007; Turner 2008). In addition, general public's perceptions of science and technology are being discussed and studied from policy makers' view point (Davison *et al.* 1997; Cajas 1999; Michael 2002; Miller 2004; European Commission 2005, 2010; Delgado *et al.* 2011; Prpić 2011; Retzbach *et al.* 2011).

However, although business enterprises are at the center of contemporary society, built upon advanced science and technology and are the main employers of students who come out of educational institutions, there have not been many studies of how business executives perceive the importance of STS and other types of cross-disciplinary knowledge. In other words, students' and teachers' perceptions of science, technology and society are also important in an educational context (Stukalina 2012), but it is critical for us to understand how business executives perceive STS in their operational context (Prpić 2011; Retzbach *et al.* 2011; King 2012; Stukalina 2012), as businesses are the pillars of modern society. Graduates taught through these cross-disciplinary curricula in higher educational institutions are the major source of human resources in these business enterprises (Škare 2011).

In this regard, a survey of business executives was conducted in this study to understand how business owners and managers perceive the value and priorities of cross-disciplinary education (i.e. STS) in connection with their business operations and executions. A questionnaire was newly developed by a focus group of professionals to examine how different knowledge domains are perceived in different aspects of business operations, such as staff training or recruitment, and related decision criteria used in their business processes. Previously developed items available in the STS literature (e.g. VOSTS) are not suitable for the purpose of this study, as those items measure very general perceptions of science and technology, such as definitions of science and technology and R&D, the effects of science and technology on each part of our society, and the images of scientists and technologists (Aikenhead et al. 1989). In this study, a questionnaire is specifically designed and developed to measure and assess how executives evaluate these cross-disciplinary knowledge related to their task and job. Furthermore, the questionnaire asks about the priorities in STS curricula design as well as the actually preferred composition of curricula.

1. Research procedure

One of the most frequently used measuring tools in STS is the VOSTS (Views On Science-Technology Society), which was developed in the 1980's (Aikenhead *et al.* 1989). VOSTS assesses what students or teachers think of technology itself as well as its social implications. VOSTS consists of eight dimensions: definitions of science and technology, society's influence on science and technology, the influence science and technology have on the society, the effect of science education in school on the society, the characteristics of a scientist, the social composition of scientific knowledge, the social composition of technology, and the epistemological stance concerning science and technology. Also, rather than resorting to a quantitative Likert-type scale, the VOST asks open-ended questions geared towards qualitative analysis.

In reality, VOSTS was developed based on surveys and interviews of Canadian high school students and may not be the most accurate match for discovering what business executives think of science and technology in terms of their business operations. For example, in VOSTS, regarding the question of what science is, the answers choices are: a field of studies, experimentation, knowledge, or an entire organization for acquiring knowledge, all of which are mostly irrelevant when it comes to business operations. As this study seeks to examine how business leaders view the importance of science and technology as it is related to the management of their businesses, such feedback on simple recognition falls short of providing accurate information for the purpose of this study.

1.1. Instrument development

The survey instrument for this study was developed in three stages as shown in Figure 1. (1) Three executives were recruited for discussing and identifying a rough list of related topics for and of their own business operations, related to STS. At the beginning of the session, the researcher briefed the participants on the goal of the session and triggered their discussion around issues involving science and technology in their businesses. The goal of this session was to identify relatively large-grained topics concerning science and technology and the use of science and technology in business operations. (2) At the second stage of instrument development, other three experts were recruited for the actual item development: two experts are academics in education and communications while third is a business executive with more than ten years of experience in electronics business. Topics identified in the first session were delivered and briefed at the beginning of a three-hour focus group session in this session. Forty questions were delivered at the end. (3) Five experts were, again, recruited separately for questionnaire refinement including a pretest. For this session, academics were recruited from different field: journalism, biology, information technology, public administration, and theology, balancing different perspectives.

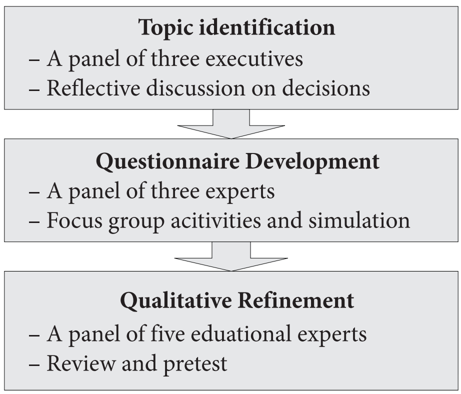

Fig. 1. Instrument development

In the first stage, eight topics emerged and were confirmed by the panel of three business executives (Table 1) as critical when they make operational decisions for their businesses. The topics include both specific and general topics. Specific topics include an identification of necessary courses while general topics include personal acceptance and tolerance levels of unfamiliar knowledge.

Table 1. Topics identified

No.	Category	Questions
1	Effects of cross-disciplinary knowledge (such as STS) on business operations	4
2	Acceptance and tolerance of cross-disciplinary knowledge	2
3	Relative importance of different knowledge fields in career development	7
4	Relative importance of different knowledge fields in recruitment	4
5	Need for cross-disciplinary education and training	3
6	Current status of cross-disciplinary education and training	3
7	Suggested positioning of cross-disciplinary education and training	5
8	Assessing priorities of different cross-disciplinary courses	12
	Total number of questions	40

In the second stage, three experts from different field of expertise (education, communication and business) were recruited for a focus group. The goal of this focus group was briefed at the beginning of the session, this being the development of actual questions for the topics identified in the first session. Eight topics were briefed at the beginning of the session, and using their own notebook, they were allowed to consult previous studies on the Internet for reference. After four hours of deliberation, forty specific questions were developed with measurement scales and other details.

Again, five experts were recruited separately from the panels in previous sessions. The goal of the third stage was to refine the questions developed in the second session. These experts were recruited from among the members of Science Technology Society Forum at Yonsei University, Seoul, Korea. The five from different departments: journalism, biology, information technology, public administration, and theology, thus balancing different perspectives. Two of the recruits had more than five years of business experience before academia. The focus of this session was on the accurate wording of questions and on the order of the questions. They were not allowed to add or exclude topic categories or questions. After the correcting and re-wording of forty questions, the final survey instrument was constructed with demographic questions.

1.2. Data collection

For data collection, business executives were recruited from various executive training programs at Yonsei University in Seoul, Korea. Initially, program coordinators were contacted by email and phone to solicit their participation. There were nine executive programs ongoing at the point of contact. Four agreed to participate in the study. Printed questionnaire were delivered on the designated day of the class. Briefing of the purpose and methods of the study was done before handing out the questionnaires. Out of two hundred and six executives enrolled in these four programs, one hundred and forty nine questionnaires were collected and returned. This was due to the high absence ratio at the beginning of the class. Four were removed due to incompleteness and finally one hundred and forty five returned questionnaires were used for the analysis. SPSS was used for the analysis.

1.3. Demographics

The demographics of the respondents are presented in Table 2. CEOs representing corporations made up the largest proportion, and executives made up over 60% of the respondents. As for the types of businesses, communication and services together accounted for over 40%, the highest proportion. Sixty two percent of the companies represented had over 100 employees, and 20% of the companies had less than 20 employees. As for college degrees, 69 of the respondents were in engineering, and 76 in humanities and social science, showing a balanced spread of different fields. Their professional areas also showed diversity with finance and manufacturing relatively less represented than other areas.

Table 2. Demographics

Business Type	Number of respondents (%)	Position	Number of respondents (%)	Number of employees	Number of respondents (%)
Commu-nication	37(25)	CEO	54(37)	Over 100	90(62)
Services	30(19)	Senior Executive	27(19)	Under 20	29(20)
Manufacturing	28(19)	Director	14(10)	21–50	19(13)
Finance	15(10)	Department Head	29(20)	51–100	7(5)
Distribution	10(7)	Manager	17(12)		
Others	25(20)	Others	4(3)		
Total	**145**	**Total**	**145**	**Total**	**145**

Professional area	Number of respondents (%)	Age	Number of respondents (%)	Undergraduate major	Number of respondents (%)
Sales	31(21)	20s	23(16)	Engineering	69(48)
Human Resources	13(9)	30s	59(41)	Social Sciences	76(52)
Finance	3(2)	40s	60(41)		
Marketing	10(7)	50s	2(1)		
R&D	8(6)	60s	1(1)		
Manufacturing	5(3)				
Planning	19(13)				
Others	56(39)				
Total	**145**	**Total**	**145**	**Total**	**145**

2. Analysis

A survey of business executives were conducted in this study to understand how they assess the importance of and need for cross-disciplinary education and training (i.e. STS) in connection with their business operations. A new questionnaire was developed and administered. One hundred and forty five data points were collected. Analyses were conducted using SPSS. For each topic of interest identified, the mean values for each question was compared against each other, testing the statistical significance of differences. For some interesting topics, more detailed analyses were conducted.

2.1. Effect of cross-disciplinary knowledge on business operations

First, the importance of science and technology for business management was evaluated at 3.75 (75%) on a five-point scale, meaning that these executives value science and technology knowledge relatively highly in their work. They also value highly the contribution of science and technology knowledge on business problem-solving ability (3.77, 75%). Interestingly, cross-disciplinary knowledge seems to be valued lightly higher than science and technology knowledge itself when it comes to the application to actual business problems (compare P2 and P3 in Table 3).

Table 3. Effects of cross-disciplinary knowledge of business operations

	Questions	Mean	Std dev
P1	Importance of science & technology knowledge on professional performance	3.7517 (75%)	1.1337
P2	Effects of science and technology knowledge on the ability to solve business problems	3.7655 (75%)	1.0001
P3	Effects of cross-disciplinary knowledge on the ability to solve business problems	3.9862 (79.7%)	0.9353
P4	Importance of understanding socio-cultural changes incurred by technological advancement	3.9310 (78.6%)	0.8552

At a glance, P3 and P4 scored higher than P1 and P2, showing a tendency to view cross-disciplinary ability to combine technology with other areas of knowledge to be more important than the influence of technology or technological knowledge alone (P3). An understanding of the socio-cultural changes arising from technological advancement was awarded higher scores than an understanding of technology per se (P4). To verify these results statistically, pair-wise t-tests were conducted on the mean difference of each variable. The results of these tests are shown in Table 4. It was found that the means of P3 and P4 are statistically significantly higher than means of P1 and P2. Thus, it can be concluded that business executives value cross-disciplinary knowledge more than they do technological knowledge per se.

Table 4. Mean difference test for knowledge assessment of different areas

	Mean	Std dev	Std err	t-value	Sig
P1-P2	–0.01379	0.70697	0.05871	–0.235	0.815
P2-P3	–0.22069	0.96802	0.08038	–2.745	0.007
P3-P4	0.05517	0.77082	0.06401	0.862	0.390
P4-P1	0.17931	1.10973	0.09216	1.946	0.054

Next, the responses were grouped according to the respondents' undergraduate major and an independent sample t-test was conducted for P1 to P4 (Table 5). The purpose of this test is to determine if the group may have different views on different types of knowledge. Interestingly, the results showed that those with degrees related to science and technology placed somewhat higher value on science and technology than those with humanities and social science degrees. However, no significant differences were found in terms of the valuing cross-disciplinary knowledge in terms of their business operation. The reason behind technology majors valuing technology more than those with humanities backgrounds seems to be a natural partiality stemming from their education. There is no statistically significant difference between the two groups regarding their assessment of cross-disciplinary knowledge; this may be due to the fact that beyond their educational training, they must have embodied the importance of cross-disciplinary skills in their business practice.

Table 5. Group means for the area knowledge assessments

	Group	N	Mean	Std dev	Std err	t-value	Sig
Importance of science & technology (P1)	SE	69	4.0870	0.88682	0.10676	3.525	0.001
	HS	76	3.4474	1.24788	0.14314		
Science & technology knowledge on problem solving (P2)	SE	69	4.0000	0.80440	0.09684	2.751	0.007
	HS	76	3.5526	1.11229	0.12759		
Cross-disciplinary knowledge on problem solving (P3)	SE	69	4.0290	0.89065	0.10722	0.523	0.601
	HS	76	3.9474	0.97836	0.11223		
Understanding social changes (P4)	SE	69	3.9420	0.83814	0.10090	0.147	0.883
	HS	76	3.9211	0.87580	0.10046		

*ST: science and technology majors, HS: humanities and social science majors.

2.2. Acceptance and tolerance of cross-disciplinary knowledge

The next set of questions evaluated the respondents' acceptance and tolerance of knowledge from domains different from their own (Table 6). As technologies develop further and becomes integrated more deeply in our modern society, the acquisition of new information is becoming more critical. These questions are included based on the idea that especially in managing business, application of knowledge encompassing different fields in a convergent manner are more important that in-depth knowledge itself in a specific domain. P5 asks about their acceptance and tolerance to knowledge in humanities and social sciences. The mean score was 3.2569 (65%). P6 asks about the acceptance and tolerance of knowledge related to science and technology. The mean was 3.1862 (64%), which is slightly lower than that of the other group but of no statistical significance.

An independent sample t-test was performed to compare the means of the two groups: science technology majors (ST) and humanities and social science majors (HS). Regarding the question on the tolerance level of ST people for knowledge in different area, the ST group evaluates themselves as being more tolerant (3.46, 69.2%) while the HS group believe ST majors were not as tolerant of knowledge in other area (3.07, 61.4%). These two group means were significantly different (t = 2.732). With regards to the question on the tolerance level of HS people, the two groups of respondent seem to agree at a similar level (3.16 and 3.11, respectively with no statistical significance).

Table 6. Acceptance and tolerance for knowledge in other domains

	Group	N	Mean	Std dev	Std err	t-value	Sig
P5	All	145	3.2569				
	ST	69	3.4638	0.91683	0.11037	2.732	0.007
	HS	76	3.0677	0.82746	0.09555		
P6	All	145	3.1862				
	ST	69	3.2609	0.91799	0.11051	0.963	0.337
	HS	76	3.1184	0.86359	0.09906		

2.3. Relative importance of different knowledge fields in the area of career development

The next set of questions was related to important human resource management questions: which fields of knowledge these business executives viewed as more important when promoting their employees. Regarding the detailed questions in this part of the survey, the experts in the second phase of instrument development took a long time to come to an agreement. Rather than making a coarse division of knowledge into technology and humanities, suggestions were made by panel members to use a slightly more detailed but meaningful typology of the type that is commonly used in business. It took a considerable amount of time to decide whether this was conducive for the purpose of this study. Each classification in the suggested typology was discussed in detail, after which the following seven subareas of knowledge were included for these questions: science and technology (U1), humanities and social sciences (U2), creativity and art (U3), economy and policy (U4), business management (U5), social ethics (U6), and organizational communications (U7).

The means of responses are presented in Table 7. Organizational communication was assessed as highest (4.64/92.8%) while science and technology was lowest (3.63/72.6%). Interestingly, score increases from U1 to U7 incrementally. To verify the differences in the means of these seven areas statistically, an independent sample t-test was conducted for each adjacent pair. Statistically significant differences in means were found in every pair except two: between U3 and U4 (creative art and economic policy), and between U5 and U6 (business management and social ethics).

Most of all, communication skills seems to be most critical for being promoted, with ethics and management-related knowledge following. An understanding of economy/policy and creativity/art comes next, while domain knowledge comes last. This is consistent with previous findings in human resource research (Allred *et al.* 1996), in which cross-disciplinary knowledge and collaborative leadership along with good personal traits of flexibility, integrity and trustworthiness were critically emphasized to become a good manager.

Table 7. Comparing the importance of seven knowledge areas for deciding on promotion

Area	Mean	Diff	Mean diff	Std dev	Std err	t-value	Sig
Science and technology (U1)	3.6276	U1-U2	−0.23448	1.09933	0.09129	−2.568	0.011
Humanities and social sciences (U2)	3.8621	U2-U3	−0.14483	0.90507	0.07516	−1.927	0.056
Creativity and art (U3)	4.0069	U3-U4	0.04138	1.01294	0.08412	0.492	0.624
Economy and policy (U4)	3.9655	U4-U5	−0.23448	0.68732	0.05708	−4.108	0.000
Business management (U5)	4.2000	U5-U6	−0.03448	0.88517	0.07351	−0.469	0.640
Social ethics (U6)	4.2345	U6-U7	−0.40690	0.81220	0.06745	−6.033	0.000
Organizational communications (U7)	4.6414						

2.4. Relative importance of different knowledge orientations in recruiting

Next four questions dealt with the importance of knowledge areas referenced in recruiting new employees. R1 asks about knowledge of their own academic area while R2 asks about knowledge about the business of the company for which they want to work. R3 ask about the importance of knowledge related to STS while R4 explores the importance of general cross-disciplinary knowledge (Table 8). The seven knowledge area used in the previous section regarding the promotion decision were not used here because decision criteria for recruiting are not as complicated as promotion cases. From the perspective of business operations, it seems natural for executives to value practical knowledge more than academic knowledge. Together with the analyses of the seven knowledge area mentioned above, it can be concluded that business executives value cross-disciplinary knowledge and application capability much more than in-depth academic knowledge in a particular area.

Table 8. Differences in means for general knowledge areas for recruiting

	Content	Mean	Diff	Diff	Std dev	Std err	t-value	Sig
R1	Knowledge of one's own academic area	3.7448	R1-R2	−0.26897	0.90719	0.07534	−3.570	0.000
R2	Business specific knowledge	4.0138						
R3	STS	3.6690	R3-R4	−0.46207	0.88992	0.07390	−6.252	0.000
R4	Cross-disciplinary knowledge	4.1310						

Therefore, it can be expected the cross-disciplinary knowledge would be valued somewhat higher than STS, as STS seems to be more specific. A comparison of R3 and R4 met this expectation. We found statistically a significant difference between R3 (3.67, 73.4%) and R4 (4.13, 82.6%). General cross-disciplinary knowledge seems to be valued much higher than specific STS-related knowledge (Coll, Zegwaard 2006). This can be ascribed to the fact that the range of cross-disciplinary knowledge is seen as more comprehensive than STS-related knowledge.

2.5. Need for cross-disciplinary education and training

The next set of questions was geared towards assessing the need for cross-disciplinary training. The first question asks about the need for human and social science education for science and technology people in business (N1), while the second asks about the need for science and technology education for human and social science people in business (N2). Compared to the questions in other sections, the means of N1 and N2 were found to be relatively high with no statistically significant differences (4.10/82% for N1 and 4.03/80.6% for N2), signifying the importance of cross-disciplinary knowledge in business operations. Table 9 presents the t-test results.

Table 9. Need for cross-disciplinary training

Need for	Mean	Diffe-rence	Diff	Std dev	Std err	t-value	Sig
N1: Humanities & social science education for science & technology people	4.1034	N1-N2	0.06897	0.66306	0.05506	1.252	0.212
N2: Science & technology education for humanities and social science people	4.0345	N2-N3	–0.48966	0.69838	0.05800	–8.443	0.000
N3: Cross-disciplinary education as promoted higher	4.5241	N3-N1	–0.42069	0.70385	0.05845	–7.197	0.000

N3 explores whether cross-disciplinary education becomes more and more important as an employees are promoted to a higher rank in business. The mean of N3 was 4.52 (90.5%), and was found to be significantly higher than N1 and N2. This is consistent with findings in other areas (Chen *et al.* 2005), in which cross-disciplinary knowledge relates to corporate entrepreneurship.

2.6. Status of cross-disciplinary education and training

Next, the survey inquired into the current status of cross- and inter-disciplinary education and training programs in place. The questions along with the means and standard deviations are reported in Table 10. First, of all education areas, the proportion of science and technology education was scaled at 20%, 40%, 60%, 80%, and 100% (E1). The mean for E1 was 2.7448 (roughly 54.89% of all education and training). This was slightly higher than the expected value.

Question E2 and E3 examine the proportions of cross-disciplinary training. E2 asks about relative frequencies of science and technology education given to humanities and social science majors while E3 asks about the relative frequency of education related to humanities and social science given to science and technology majors. The answer was scaled into five levels: never, once or twice a year, once or twice a quarter, once or twice per month, and constantly at work. The means for these questions were 2.81 and 2.86, respectively, which may lead to the conclusion that cross-disciplinary training is given at least once but less than twice every quarter.

Table 10. Current status of cross-disciplinary training

	Questions	Mean	Std dev
E1	Proportion of science & technology education and training	2.74	1.110
E2	Science & technology training for humanities & social science majors	2.81	1.429
E3	Humanities & social science training for science & technology majors	2.86	1.422

An interesting and serendipitous finding is worth mentioning here. When we compared the means of E1 in the two groups (the science and technology major group and humanities and social science major group), we found statistically significant differences. The science and technology major group think education and training related to science and technology accounts for about 63.48% (3.17) of all training, whereas the humanities and social science major group think the proportion is somewhat lower, at 47.11% (2.36), which represents cognitive dissonance between these two groups for a seemingly objective question (Table 11). This can be interpreted as the humanities and social science major group's thirst for education and training related to science and technology being greater than that felt by their counterparts. Alternatively, they may not realize some of the training sessions are related to science and technology. Further studies are necessary to investigate the cognitive bias or dissonance causing this difference.

Table 11. Two-group mean differences for training status

	Group	N	Mean	Std dev	Std err	t-value	Sig
N1	ST	69	3.1739	1.01397	0.12207	4,755	0.000
	HS	76	2.3553	1.05456	0.12097		

2.7. Suggested positioning of cross-disciplinary education and training

The next set of questions asked about the suggested positioning of cross-disciplinary courses of education and training (from L1 to L4). respondents were asked to prioritize the proper positioning appropriate for cross-disciplinary education and training: (1) as undergraduate common courses taught across disciplines; (2) as an undergraduate major; (3) as a professional graduate school; and (4) as corporate re-training program after employed. Table 12 presents the frequency count for the responses. The response frequency counting undergraduate major as most appropriate was found to be 14 out of a possible 145 (9.7%), while this as least appropriate was counted 67 (46.2%), which implies that cross-disciplinary education and training as an undergraduate major is not preferred at all by these business executives.

As shown in Table 12, executives suggest corporate training a the most appropriate position for the cross-disciplinary program (50 out of 145) and a graduate major as the second most appropriate (42 out of 145). Undergraduate common courses received 39 out of 145 possible votes as most appropriate. Compared to the others, the undergraduate major enticed only 14 votes out of a possible 145. The larger discrepancy between the undergraduate major and the other three options suggests that rigorous training in a single paradigmatic discipline is a necessary condition for goo cross-disciplinary training. Executives seem to view undergraduate majors as a corner-stone before anything can be built.

It seems that, though they think this type of education is critical for their business operations, this type of training cannot be achieved before students choose their own area of expertise. Cross-disciplinary education and training can only be done after securing specialized knowledge; moreover, this specialization can only be built with new, consilient and applied knowledge (Gudas 2009). This is more evident when examining the fourth row of Table 12, which shows the least frequent choices. Those who chose the undergraduate common course as the least ideal were highest in terms of frequency (67), while the frequencies of the other three were only 42, 11, and 25.

Table 12. Frequency counts for the positioning of cross-disciplinary training

Priority	**Undergraduate common (L1)**	**Undergraduate major (L2)**	**Graduate major (L3)**	**Corporate training (L4)**
1	39 (26.9)	14 (9.7)	42 (29.0)	50 (34.5)
2	19 (13.1)	26 (17.9)	54 (37.2)	46 (31.7)
3	45 (31.0)	38 (26.2)	38 (26.2)	24 (16.6)
4	42 (29.0)	67 (46.2)	11 (7.6)	25 (17.2)

*frequency (%)

Especially in engineering, cross-disciplinary education and training was strongly emphasized pointing out engineering demands practical application of integrated cross-disciplinary knowledge in the field. Hence progressively more cross-disciplinary elements were added to the undergraduate curriculum and were emphasized, and enforced (Adams *et al.* 2011; Litzinger *et al.* 2011). However, the executives, here may think otherwise. It is suggested here that the path for proper cross-disciplinary education starts from appropriate disciplinary training at the undergraduate level (Borrego, Newswander 2008). As this finding somewhat contradicts the current trend in curricular development in engineering schools, it might need to be investigated further in comparative studies.

2.8. Assessing the priorities of cross-disciplinary courses

The last set of questions concerned the importance of actual course offerings of a cross-disciplinary nature to be offered in this type of education and training program. A list of courses was built from an Internet search and from expert input at the second phase of survey development. After refinement, the expert panel formulated a list of twelve courses most commonly offered in this type of program across the globe, as listed in Table 13. Here, the respondents were asked to rate the importance of each subject using a five-point Likert scale. Means for each course are presented in Table 13, with the highest at the top and lowest at the bottom. A matched samples t-test comparison was conducted for sets of adjacent pairs to test whether the differences were statistically significant.

Table 13. Importance ratings of twelve cross-disciplinary courses

Courses	Mean	Diff (var)	Diff	Std dev	Std err	t-value	Sig
Science & technology communications (C12)	4.3448	C12-C9	0.24828	0.86226	0.07161	3.467	0.001
Technology Management (C9)	4.0966	C9-C8	0.07586	0.80866	0.06716	1.130	0.261
Science & Technology Entrepreneurship (C8)	4.0207	C9-C1	0.06897	0.86326	0.07169	0.962	0.338
Science Technology Society (C1)	3.9517	C1-C6	0.03448	0.85321	0.07086	0.487	0.627
Science & Technology Policy (C6)	3.9172	C6-C10	0.01379	1.02053	0.08475	0.163	0.871
Science Technology Ethics (C10)	3.9034	C10-C11	0.01379	0.74523	0.06189	0.223	0.824
Cyber Ethics (C11)	3.8897	C11-C7	0.04828	1.20952	0.10044	0.481	0.632
Technology Market Analysis (C7)	3.8414	C7-C5	0.02759	1.06030	0.08805	0.313	0.755
Science Tech Literature (C5)	3.8138	C5-C4	0.39310	0.74811	0.06213	6.327	0.000
Science Technology Art (C4)	3.4207	C4-C3	0.08276	0.72172	0.05994	1.381	0.169
Science Technology Philosophy (C3)	3.3379	C3-C2	0.09655	0.81925	0.06803	1.419	0.158
History of Science & Technology (C2)	3.2414						

Three out of twelve courses marked a mean score higher than four: science technology communications (4.34), technology management (4.10), and science technology entrepreneurship (4.02). This finding can be interpreted to mean that business executives highly value flexible communicative competence, which may be obtained by employees trained in a cross-disciplinary manner. Executives gave prominently higher marks to science technology communications. It can thus be inferred that they also value highly business-related applications of this cross-disciplinary knowledge as they gave relative high marks to technology management and related entrepreneurship.

Between scores of 3.5 and 4, six courses were positioned: science technology society (3.95), science technology policy (3.91), science technology ethics (3.90), cyber ethics (3.88), technology market analysis (3.84), and science technology literature (3.81). These second-group courses are mostly related to social issues. Three courses were rated below 3.5 with statistically different mean scores compared to the second group, which was related to social issues of science and technology. These courses were science technology art (3.42), science technology philosophy (3.34), and history of science and technology (3.24). The last group deals issues related to humanities of science and technology.

In sum, twelve courses were grouped into three categories based on the mean values of the importance rating. These three categories of courses are termed as follows: (1) Science Technology Enterprise (STE); (2) Science Technology Society (STS); and (3) Science Technology Humanities (STH) as presented in Figure 2. The first group (STE) received highest importance rating from the business executives. STE courses deals directly with business-related issues using knowledge of science and technology, such as entrepreneurship, organizational communication, and management. The second group of courses (STS) mostly deals with social approaches to science and technology including policy and market analyses. Ethical issues are also dealt with in these courses as well as literary explications related to science and technology. The third group (STH) seems to deal with issues indigenous to science and technology, such as philosophy, history and arts. Philosophy investigates the supporting internal logics of science and technology while history documents developments in the areas of science and technology (Fig. 2).

Science, Technology and Enterprise: *STE*
(over 4.0)
– Science Technology Communcations
– Science Technology Management
– Technology Entrepreneurship

Science, Technology and Society: *STS*
(between 3.5~4.0)
– Science Technology and Social Phenomena
– Science Technology Policy
– Science Technology & Ethics
– Cyber Ethics
– Technology Market Analysis
– Science Technology Literature

Science, Technology and Humanity: *STH*
(between 3.0~3.5)
– Science Technology Arts
– Science Technology Philosophy
– Science Technology History

Fig. 2. Grouping of cross-disciplinary courses

Results, discussion and conclusion

This study examined and analyzed business executives' understanding of the need for cross-disciplinary education and training related to science and technology in business enterprises for coming knowledge based smart working era. Survey instruments previously developed to measure perceptions of science and technology seemed inappropriate in business contexts as most of previous surveys were concerned about the education and training of young students and teachers. Thus, a new questionnaire was developed via phased refinements by experts in the field. Eight topical areas deemed critical in making operational decisions for their businesses were identified by a panel of three business executives during the first phase of instrument development. Specific topics included identifications of necessary courses while general topics included personal acceptance and tolerance levels of unfamiliar knowledge. Forty questions were developed for these eight topical areas, reviewed, and pretested by another group of experts before the actual questionnaire administration. For the actual survey, business executives were recruited from various executive training programs. One hundred and forty five data points were collected and used for in-depth analysis.

Executives value science and technology very highly and understand that it helps their employees solve business problems. Also, in terms of subareas of knowledge, executives value organizational communications very highly, as it integrates several areas of cross-disciplinary knowledge, followed by social ethics, business management, economy and policy, creativity and arts, humanities and social sciences, and science and technology, in this order. When recruiting new hires, it seems that they also emphasize cross-disciplinary knowledge beyond the specifics of majors in the college. They understand the critical need for cross-disciplinary training when promoted to a higher level of management, and they conduct these types of training events at least once every quarter. Most executives demand that their recruits have college-level cross-disciplinary education and training, though they are willing to offer post-hire in-house training on these issues. Executives view cross-disciplinary education and training in terms of three subareas: Science Technology Enterprise (STE), Science Technology Society (STS), and Science Technology Humanities (STH) in this order of importance.

Analysis results suggest that business executives maintain clear understanding that science and technology are critical elements for today's businesses and indispensable for our lives and society. Technologies have been undergone tremendous specialization leading people to specialize in focused domain knowledge in industrialized and manufacturing-centric business operations. However, in today's complex environment with different technologies converging with each other creating novel ideas and pushing envelopes for new applications of old ideas, cross-disciplinary integration of knowledge is realistically a necessity for practitioners to survive, executives confirm.

Findings of this study provide a good basis for the development of future cross-disciplinary education and training programs in coming smart working era. However, this study has its limitations. The questionnaire newly developed in this study may need further validation via empirical replications in a variety of context with larger samples. Though it went through a rigorous three-step refinements process during several expert panels, the process was mostly qualitative. Also, the coverage of issues may not be comprehensive enough to reveal all of the relevant aspects of science and technology as viewed from a business operations perspective. Only replications and refinement via qualitative and quantitative research would advance our understanding in this area.

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Jungwoo LEE. He is a Professor of Systems, Technologies and Information in the Graduate School of Information at Yonsei University, Seoul, Korea. He teaches graduate level students and executives on topics on and around the changing nature of work and business by information and communication technologies. At Yonsei, he served as the director of IT Strategy and Policy Research Institute, CEO IT program, and the executive director for the Yonsei University Newspaper and Broadcasting. His external services includes the Director of Smart Work Forum, the President of the Data Governance Forum, the President of the Korea Society for e-Business Studies, the Advisory Committee Chair for the Federation of Korean Information Industries. Other advisory capacities include the Government of Seocho, the Universal Content Identifier Users Forum, the National Digital Library, and other public organizations and private firms. He has published over 20 papers in international journals, over 40 in Korean journals, and numerous book chapters as well as articles in practitioner magazines. Aside from the academic responsibilities, he had published own columns in the Digital Times and the Segyeilbo, and served as a main anchor for a news program at the M-Money Broadcasting Station specialized in economic analysis. He holds a PhD and MS in computer information systems from Georgia State University, MBA from Sogang University, BA in English Language and Literature from Yonsei University. He has 7 years industrial experience before entering the academics, and recently spent a sabbatical year at the Samsung Economic Research Institute as a visiting scholar conducting the industrial grade research.