TEACHING INTEGRATED STEM IN KOREA: STRUCTURE OF TEACHER COMPETENCE

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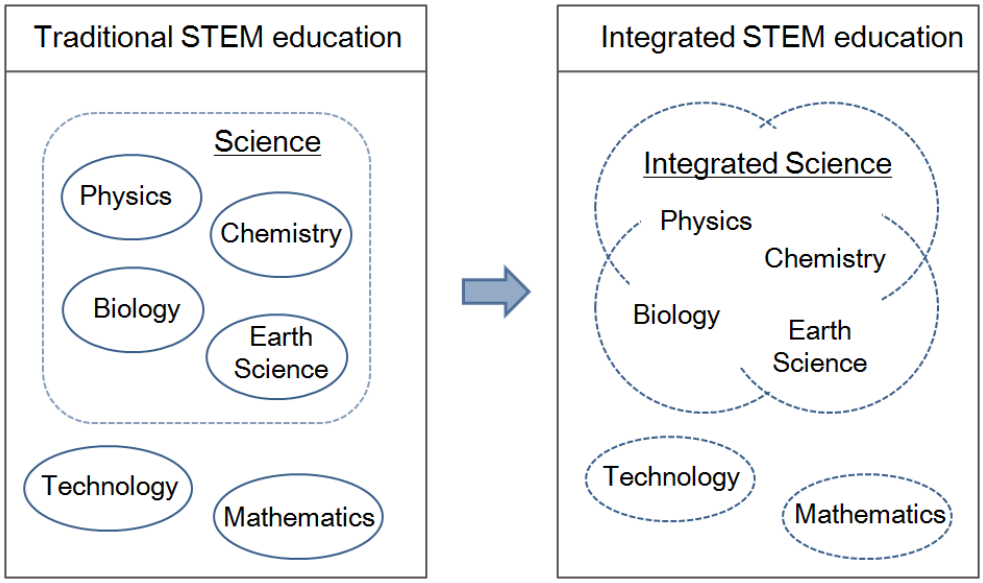
Abstract *The structure of teacher competence of integrated STEM education in Korea was investigated by literature and qualitative research. It was found that teacher competence is composed of three domains of cognitive characteristics, instructional skills, and affective characteristics as an important factor for teachers to carry out desirable integration in STEM education. By using behavioral event interview technique, qualitative data were collected from 11 superior and average teachers. The results showed that critical items of three domains of teacher competence are as follows: 1) teachers' knowledge on other STEM subjects and ability to link between other subjects; 2) student centered activity and project based curriculum; 3) communication and cooperation between teachers and willingness and enthusiasm on integrated STEM. Based on these results, a structural model of teacher competence forintegrated STEM education in Korea was proposed.*

Keywords: integrated STEM, STEAM, teacher competence, behavioral event interview

1. BACKGROUND

Education in science and technology areas was accomplished by teaching each STEM subjects of science and technology and mathematics respectively. And traditionally science subjects were taught separately as 4 individual disciplines of physics, chemistry, biology, and earth science. In integrated STEM education, 4 individual science subjects are combined as a unified "integrated science" and usually taught by a single teacher or a team of teachers in cooperation. Technology and mathematics are taught as a discrete subject but putting together with an integrative approach. Interdisciplinary areas of subjects and real world problems related to technology and engineering are emphasized.

- STEM (Science, Technology, Engineering, and Mathematics) education



In terms of STEM education in secondary school system of Korea, in middle school, science is taught as integrated form (physics, chemistry, biology, and earth science are unified). But in high school, science is taught as integrated form only for first year(10th) but divided into 4 individual subjects in later years(11, 12th grade).

- STEM Education in secondary school system of Korea

Middle School	High School	
7th - 9th	10th	11th, 12th
Science (integrated)	Science (integrated)	Physics I, II Chemistry I, II Biology I, II Earth Science I, II
Technology-Home Living		None
Mathematics		

In Korea, several curriculum revisions have been implemented to lay stress on integration. STEAM (Science, Technology, Engineering, Arts, and Mathematics) education, by adding Arts into STEM education, has been adopted in education system and a number of related programs has developed by Ministry of Education, Science and Technology (MEST) and Korea Foundation for the Advancement of Science & Creativity (KOFAC) since 2011 (KOFAC, 2011; MEST, 2012; Oh, 2015; Sim, Lee, & Kim, 2015).

However, there have been some controversies about the professionalism of teachers as executors of

convergence education (Oh, 2015). Teachers have been lacking a grasp of STEAM education and integrated curriculum (Han & Lee, 2012; M. S. Lee, 2013; Lim, 2012; Shin et al., 2012). Teachers have been felt serious difficulties and troubles in executing STEM education (Shin & Han, 2011). Some studies revealed that teaching anxiety of secondary science teachers was stronger when teaching non-major fields of science (Kang, 2015; Sung, 2011). Hence, it has become a major issue that in order to accomplish integrated education teacher competence has to be enhanced (Oh, 2015).

2. OBJECTIVE

For the successful implementation of the integrated STEM education, teacher competence could be a key element to teach integrated subjects more efficiently (Cooper, 2011; Honey, Pearson, and Schweingruber, 2014; Johnson, Peters-Burton, & Moore, 2015; Leung, 2006). The aim of this study is to explore how teachers understand their practice in teaching STEM subjects with integrative approaches and to investigate what are critical factors of teacher competence, which is considered that it is composed of cognitive characteristics, instructional skills, and affective characteristics (Choi, Lee, Jang, & Kim, 2009; Hur, 2011; Klein & Richey, 2005; Lee & Lee, 2010; Medley & Crook, 1980), as an important factor for teachers to carry out desirable integration in STEM education and for student to develop STEM literacy.

The research questions are:

1) What is the teachers' perception on teaching STEM subjects as an integrated discipline?

2) What do teachers perceive to be essential factors in terms of teacher competence in integrated STEM?

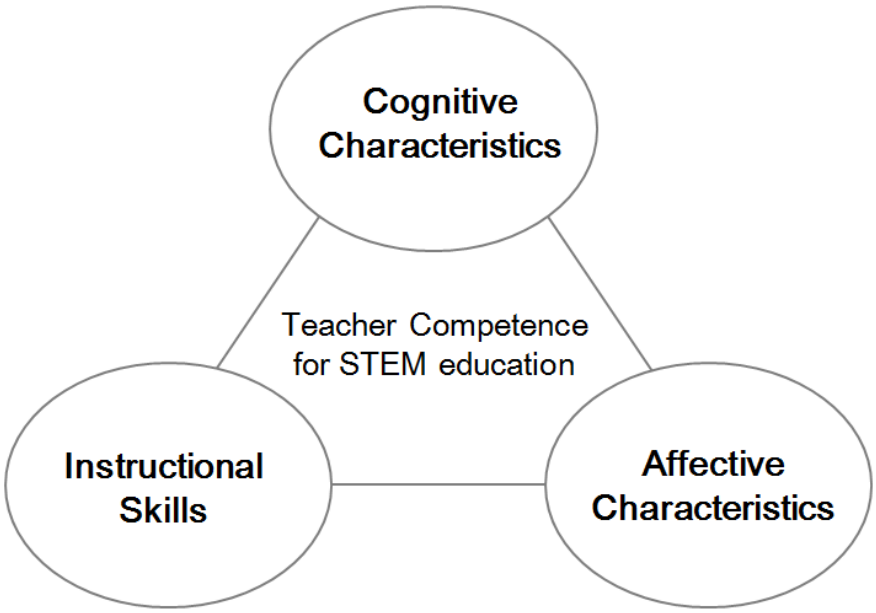


Figure 1. Conceptual framework for investigating teachers' understanding and teaching of STEM

3. METHODOLOGY

The structure of teacher competence for integrated STEM education in Korea was investigated by literature and qualitative research. Based on literature research, this study assumed that teacher competence consists of three domains of cognitive characteristics, instructional skills, and affective characteristics. By employing BEI (Behavioral Event Interview) technique (Spencer & Spencer, 1993), this study has interviewed 11 secondary school teachers of STEM subjects and analyzed interview data using Nvivo 11 software program.

Interview participants are asked to describe specific examples of cases where they have successfully taught integrated STEM classes overall, including preparation for class, instructional process, and assessments. Particularly, in case of science teacher, observations about integrated science classes which in some cases has been instructed separately by teachers who have majored one subject in university among 4 different science disciplines of physics, chemistry, biology and earth-science are asked. It is also asked that teacher's perception on the integrated curriculum and teacher competence which is required to achieve successful convergence education in terms of three different aspects of cognitive characteristics, instructional skills, and affective characteristics.

- Participants

(*: superior teacher, O : yes, X : no)

Subject & Teacher no.	Physics			Chemistry		Biology		Earth science		Technology	Mathematics
	#1*	#2*	#3	#4*	#5	#6*	#7	#8*	#9*	#10*	#11
Teaching experience (years)	30	11	5	26	7	29	6	14	10	15	7
Teacher training program for integrated education	O	O	O	O	O	O	O	O	O	O	X
Teaching experience of integrated STEM education	O	O	O	O	O	O	O	O	O	O	O
Participation in integrated STEM teacher study group	O	O	X	O	X	O	O	X	X	X	X

4. RESULTS

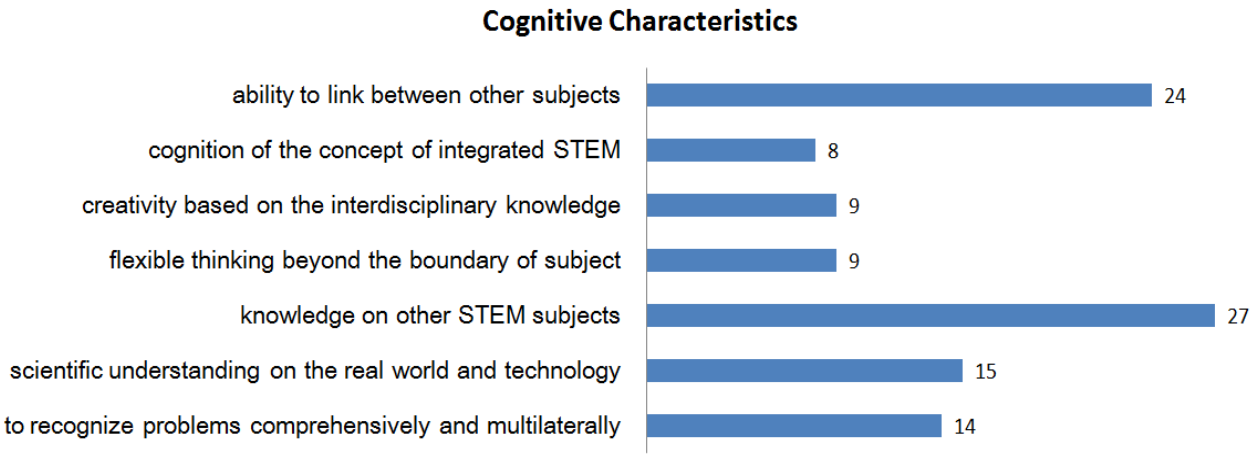
- Cognitive Characteristics

(Number: number of coding references)

Subject & Teacher no. / Critical factors	P			C		B		ES		T	M
	#1	#2	#3	#4	#5	#6	#7	#8	#9	#10	#11
ability to link between other subjects	0	4	1	1	2	0	3	4	4	4	1
cognition of the concept of integrated STEM	0	1	1	0	2	0	2	2	0	0	0
creativity based on the interdisciplinary knowledge	0	1	2	0	1	0	2	0	1	1	1
flexible thinking beyond the boundary of subject	0	2	0	1	1	0	0	2	3	0	0
knowledge on other STEM subjects	1	4	2	1	5	2	3	5	1	2	1
scientific understanding on the real world and technology	1	4	1	1	2	1	2	1	1	1	0
to recognize problems comprehensively and multilaterally	0	2	1	0	4	0	3	1	1	1	1

All of the participants have commonly agreed that ‘knowledge on other STEM subjects’ is one of the most important competence of teacher. Most of teachers felt “a lack of expertise and self-confidence in teaching subjects other than their own major subject which has majored for BS degree in university education”. In the case of “science”, it is found that integrated STEM instruction in high school undergoes more difficulties than middle school due to insufficiency of knowledge. However, with increasing teaching experience these difficulties are noticeably reduced by increasing comprehensive understanding on science in general (#1). Other aspects of cognitive characteristics frequently pointed out by participants are ‘ability to link between other subjects’, ‘scientific understanding on the real world and technology’, and ‘to recognize problems comprehensively and multilaterally’. The other significant responses on cognitive characteristics are: ‘cognition of the concept of integrated STEM’ (#2, #3, #5, #7, #8), ‘creativity based on the interdisciplinary knowledge’ (#2, #3, #5, #7, #9, #10, #11), and ‘flexible thinking beyond the boundary of subject’ (#2, #4, #5, #8, #9).

Most of teachers participated in the interview agreed that teacher retraining program were valuable to obtain new knowledge on other discipline of STEM and helpful for integrated instruction. Participants also pointed out that teacher research activities such as teacher study group, teacher association, and professional learning communities are helpful for increasing teaching competence and for sharing and developing teaching materials. On the other hand there are also concerns about integrated instruction only for sake of arousing interest without teaching basic principles and concept of science.



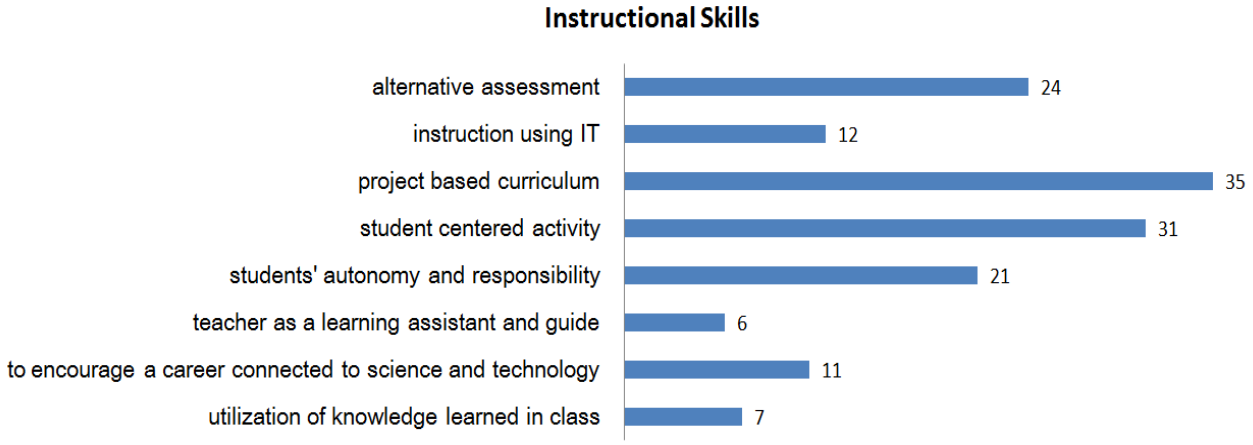
- Instructional Skills

(Number: number of coding references)

Subject & Teacher no. / Critical factors	P			C		B		ES		T	M
	#1	#2	#3	#4	#5	#6	#7	#8	#9	#10	#11
alternative assessment	1	3	3	3	1	1	1	4	1	5	1
instruction using IT	1	2	0	0	3	2	0	0	1	2	1
project based curriculum	2	4	1	2	3	5	2	3	2	8	3
student centered activity	0	8	4	2	1	4	2	4	3	3	0
students' autonomy and responsibility	1	6	3	0	0	1	0	2	0	7	1
teacher as a learning assistant and guide	0	3	0	0	0	0	0	1	0	2	0

to encourage a career connected to science and technology	0	3	0	0	1	1	2	1	1	2	0
utilization of knowledge learned in class	0	1	3	0	0	0	0	0	0	3	0

The interview results showed that the instructions were turning away from traditional instruction method, mainly consisted of group study putting emphasis on student centered activity and interaction between students. They comprised curriculum based on real world problems and problem-based learning. Environmental and ecological problems have been used as frequent project themes. All participants stated project based curriculum and alternative assessment responsible for integrated STEM education as critical factors. Teacher #1, #2, #3, #6, #8, #10, #11 have believed that provision of students' autonomy and responsibility is also important. Teachers have played a significant role as a learning assistant and guide (#2, #8, #10) and provided opportunities for utilization of knowledge learned in class (#2, #3, #10). And not only teachers themselves they have encouraged students to utilize IT technology such as using presentation tools and making UCC (#1, #2, #5, #6, #9, #10, #11). They have encouraged students to have a career connected to science and technology (#2, #5, #6, #7, #8, #9, #10). Teacher #2, #6, #8 indicated that "activities performed through integrated STEM class are recorded in student school record. They are helpful to select a career and for entrance exam". Teacher #1, #10 suggested that "to visit a class of other subject as an observer would be helpful to get new idea on teaching methods".



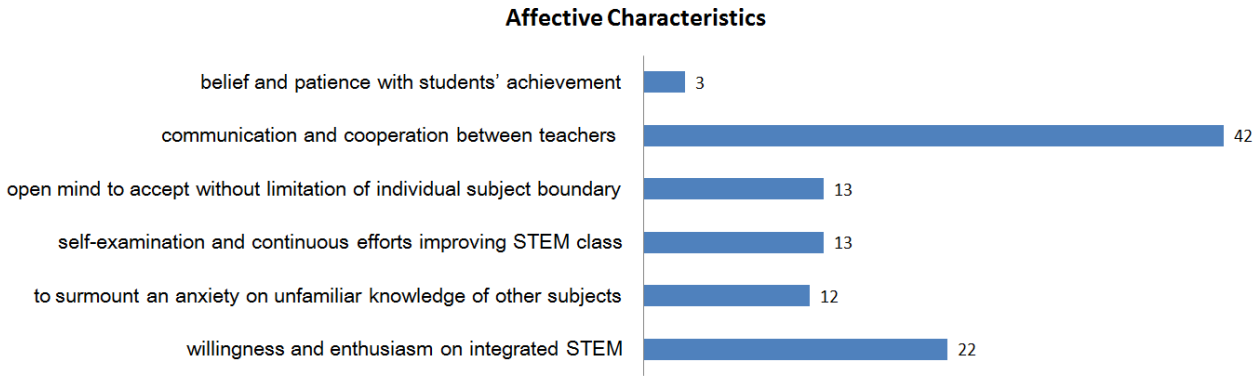
- Affective Characteristics

(Number: number of coding references)

Subject & Teacher no. / Critical factors	P			C		B		ES		T	M
	#1	#2	#3	#4	#5	#6	#7	#8	#9	#10	#11
belief and patience with students' achievement	0	1	0	0	1	0	0	0	0	1	0
communication and cooperation between teachers	2	5	1	2	5	6	5	6	3	6	1
open mind to accept without limitation of individual subject boundary	1	4	0	0	1	0	0	2	3	2	0
self-examination and continuous efforts improving STEM class	2	5	1	1	0	1	1	1	0	1	0
to surmount an anxiety on unfamiliar knowledge of other subjects	1	0	0	0	3	1	2	1	1	3	0
willingness and enthusiasm on integrated STEM	1	1	2	1	0	1	6	2	1	6	1

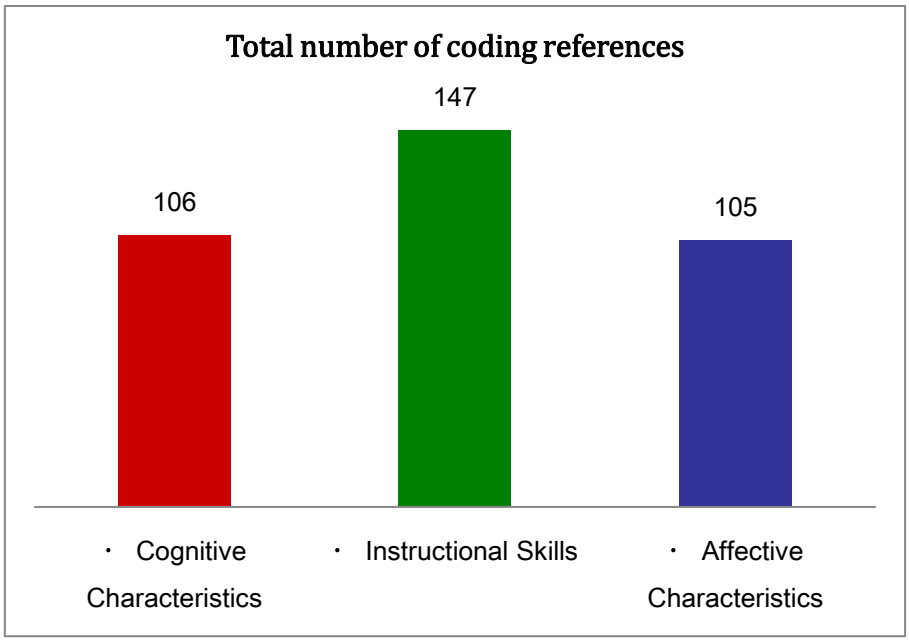
The most important points of teacher affective characteristics are 'communication and cooperation between teachers' and 'willingness and enthusiasm on integrated STEM'. Despite of no particular incentive, the willingness and the enthusiasm of teacher themselves on integrated education are found to be driving force to achieve successful integrated education. The 'communication and cooperation between teachers' are essentially required to implement integrated curriculum. However, teachers have appealed a lack of time to communicate and cooperate with other teachers due to a burden of instruction load (#1, #2, #3, #4, #5, #6) and difficulties to "re-adjusting fixed instruction time schedule" (#2, #4, #6, #7, #10, #11).

Additional crucial factors in affective characteristics sampled are as follows: 'open mind to accept without limitation of individual subject boundary' (#1, #2, #5, #8, #9, #10), 'self-examination and continuous efforts improving STEM class' (#1, #2, #3, #4, #6, #7, #8, #10), 'to surmount an anxiety on unfamiliar knowledge of other subjects' (#1, #5, #6, #7, #8, #9, #10), 'belief and patience with students' achievement' (#2, #5, #10). It is also pointed out "the importance of principals' willingness and mind to achieve convergence education" (#10, #11), and the importance of cooperation with local institutions and research communities (#2, #6).



5. SUMMARY AND CONCLUSION

In this research the teacher competence of convergence and integrated science education is categorized in three domains of cognitive characteristics, instructional skills, and affective characteristics and the distinctive traits of each domain of teacher competence perceived by STEM teachers are investigated. In cognitive characteristics, it is found that teachers' knowledge on other STEM subjects are important factor that limits teaching STEM subject in integrative method by a teacher who has trained with an individual major subject. It is pointed out that teacher retraining and teacher research activities such as teacher study group, teacher association, and professional learning communities are necessary to overcome the difficulties. In domain of instructional skills, student centered and project based instruction, and alterative assessment are found to be effective. In domain of affective characteristics, communication and cooperation between teachers and the enthusiasm, and the willingness of teachers on convergence education are extracted as a most important factor.



Based on BEI, a structure of teacher competence for integrated STEM is proposed as follows.

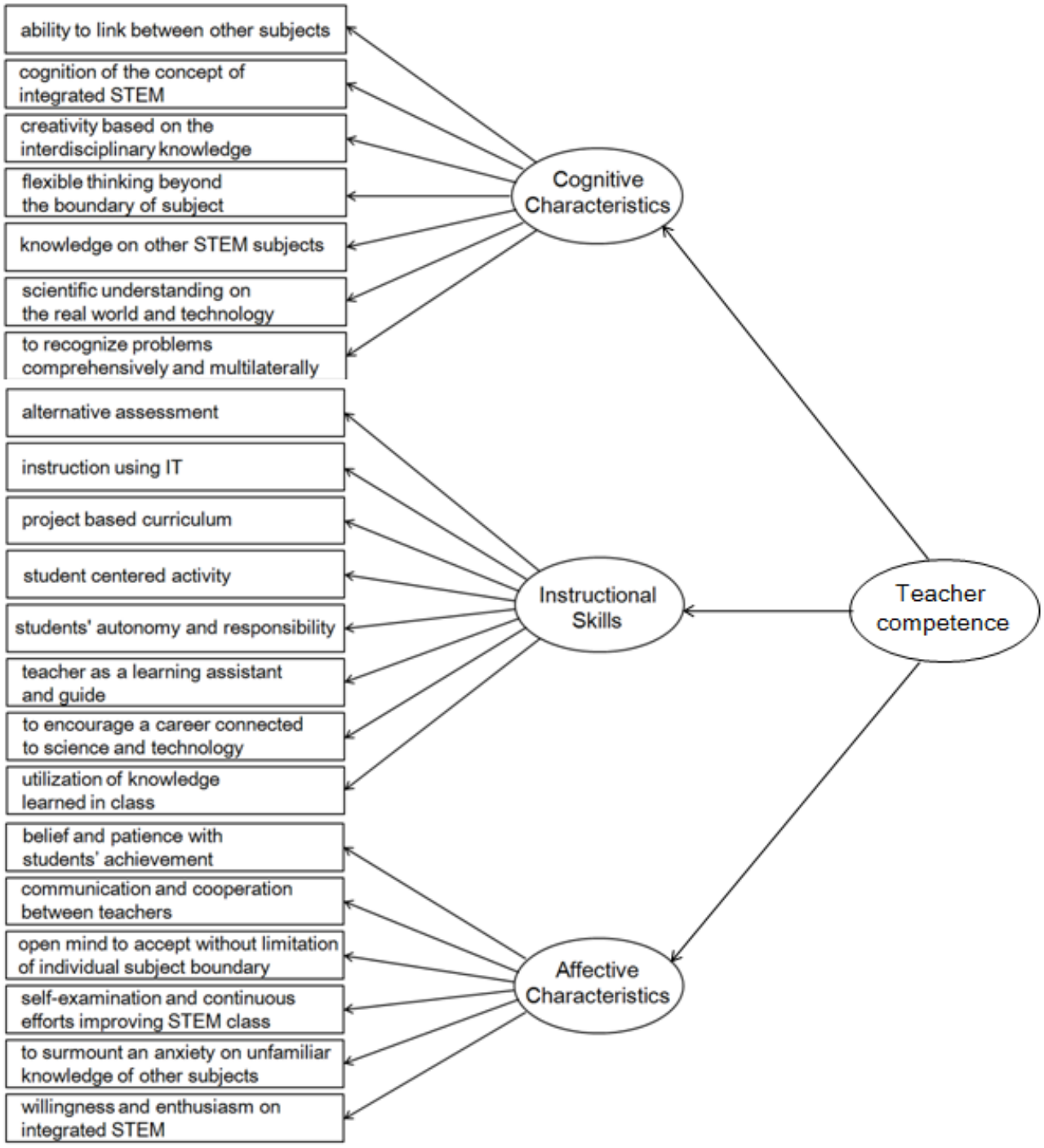


Figure 2. Structure of teacher competence for integrated STEM

The Interview result showed that although ministry of education provided a curriculum and text book for convergence and integrated science education in Korea, many teachers are not ready to accomplish integrated STEM education seriously. The teachers' perception of value and necessity of integrated STEM education is found important to be emphasized. Convergence and integrated science education which is not linked to entrance examination in Korea is one of biggest reason for not to be successful in high school education in Korea. The concept and definition of integrated STEM education are found to be different depending on teacher which is also necessary to be investigated further.

REFERENCES

Choi, J. Y., Lee, K. J., Jang, S. H., & Kim, K. J. (2009). Exploring Elementary Teachers' Core Competencies. [Exploring Elementary Teachers`` Core Competencies]. *The Korea Educational Review, 15*(3), 103-130.

Cooper, J. M. (2013). *Classroom teaching skills*: Cengage Learning.

Han, H., & Lee, H. (2012). A study on the teachers' perceptions and needs of STEAM education. *Journal of Learner-Centered Curriculum and Instruction, 12*(3), 573-603.

Honey, M., Pearson, G., & Schweingruber, H. (2014). *STEM integration in K-12 education: Status, prospects, and an agenda for research*: National Academies Press.

Hur, E. J. (2011). *The Effects of a Learning Organization on Teachers' Professionalism.* (Doctoral dissertation), Seoul National University.

Johnson, C. C., Peters-Burton, E. E., & Moore, T. J. (2015). *STEM Road Map: A Framework for Integrated STEM Education*: Routledge.

Kang, J. H. (2015). *Study on high school science teachers' attitude and anxiety toward teaching non-major field of science.* (Master's thesis), Yonsei University.

Klein, J. D., & Richey, R. C. (2005). Improving individual and organizational performance: The case for international standards. Performance Improvement, 44(10), 9-14.

Korea Foundation for the Advancement of Science and Creativity [KOFAC]. (2011). STEAM Education. Seoul: KOFAC.

Lee, J. H., & Lee, I. H. (2010). Analysis of the Structural Relationship Among Teachers' Work Load, Job Satisfaction, Organizational Commitment, Teachers' Professionalism and Schools' Educational Outcomes. *The Journal of Korean Teacher Education, 27*(2), 25-52.

Lee, M. S. (2013). The Effect of Perceiving Barriers in STEAM on Futurities toward STEAM Applications. *The Journal of Korean Teacher Education, 30*(4), 259-278.

Leung, W. L. A. (2006). Teaching Integrated Curriculum: Teachers' Challenges. *Pacific-Asian Education Journal, 18*(1).

Lim, Y. N. (2012). Problems and ways to improve Korean STEAM education based on integrated curriculum. *The Journal of Elementary Education, 25*(4), 53-80.

Lyle, M., Spencer, M. S., & Spencer, S. (1993). Competence at work: Models for superior performance. *United States: John Wiey & Sons*.

Medley, D. M., & Crook, P. R. (1980). Research in teacher competency and teaching tasks. Theory into practice, 19(4), 294-301.

Ministry of Education Science and Technology [MEST]. (2012). 2012 national plan for STEAM education. Seoul: MEST.

Oh, C. S. (2015). Issues and Tasks of the Practical Application Ways of Convergence Education in Secondary School. *Korean Journal of Educational Research, 53*(3), 229-264.

Shin, D. H., Kim, J. W., Kim, R. Y., Lee, J. W., Lee, H. J., & Lee, J. M. (2012). Development of Interdisciplinary Teacher Education Programs. *Journal of Research in Curriculum & Institution, 16*(1), 371-398.

Shin, Y. J., & Han, S. K. (2011). A Study of the Elementary School Teachers' Perception in STEAM(Science, Technology, Engineering, Arts, Mathematics) Education. *The Journal of Elementary Science Education, 30*(4), 514-523.

Sim, J., Lee, Y., & Kim, H.-K. (2015). Understanding STEM, STEAM Education, and Addressing the Issues Facing STEAM in the Korean Context. *Journal of The Korean Association For Science Education, 35*(4), 709-723. doi:10.14697/jkase.2015.35.4.0709

Sung, C. J. (2011). *Study on secondary science teachers' attitude toward teaching and teaching anxiety about non-major fields of science.* (Master's thesis), Ewha Womans University.