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Development and Validation of Evaluation Indicators for Teaching Competency in STEAM Education in Korea

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The purpose of this study is to develop and validate the evaluation indicators of teaching competency in STEAM education. The teaching competencies in STEAM education were drawn up utilizing both behavioral event interview (BEI) and a literature review. The initial evaluation indicators were then reviewed by 15 experts and two pilot tests were conducted. The revised version was administrated to 208 teachers, and the data from this survey were used to validate the factor-based model used in exploratory factor analysis (EFA) and confirmatory factor analysis (CFA). Final evaluation indicators of teaching competency in STEAM education were composed of 35 items in seven areas: Understanding of Subjects (five items); Teaching-Learning Methods (eight items); Inducing Learners to Participate in Learning (five items); Understanding of Learners (four items); Learning Environments and Circumstances (five items); Evaluation of Learners (four items); and Individual Qualification (four items). These evaluation indicators are a guideline on understanding what really matters in STEAM education and how to perform a STEAM class. Therefore, the results of this study can be standards of improving their STEAM classes by self-diagnosis, and used as consultation checklists for an effective STEAM class.

Keywords: STEAM education, teaching competency, evaluation indicator, behavioral event interview

INTRODUCTION

Recently, a major concern for the world's educational leaders is educating the future talent that can proactively and creatively solve social problems. Problems in the future will be of a complex nature with diverse aspects that cannot be solved with knowledge and will function in a specific area, and talents with convergent knowledge and creative problem-solving abilities will play a core role in the future

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(Chen, 2010; Zhao, 2012). Accordingly, the Ministry of Education in Korea has emphasized convergent education to cultivate and raise talents with convergent knowledge who cross over various academic areas and create new knowledge (Lee, 2008; Lee, 2010). Thus, the Korean government pronounced an educational plan with the goal of raising creative and convergent talents who enjoy learning and show their imagination and who have also practiced various supporting policies to strengthen science, technology, engineering, arts, and mathematics (STEAM) education in primary and secondary schools (Ministry of Education, 2010). The theoretical research that has been conducted to lay the foundation for STEAM education, including its philosophy and methodology (Kim, 2007, 2011, 2012; Kim et al., 2012; Park et al., 2012), has become the basis for development and utilization of various STEAM programs.

State of the literature

- Excellent teachers who will raise creative and convergent talents require the possession of teaching competency in convergent academic knowledge as well as practical instructional ability.
- Teacher training programs that enhance professionalism in STEAM education are mostly experiential, such as the introduction and utilization of STEAM programs, so there are limitations in enhancing teaching competency.
- Evaluation of teaching competency can provide systematic and specific plans to diagnose and enhance teaching competency.

Contribution of this paper to the literature

- Suggests more field-realistic teaching competency by including experiential competency in STEAM classes using Behavioral Event Interviews (BEIs).
- Presents valid evaluation indicators of teaching competency for STEAM education through verifications such as reliability, content validity, construct validity, convergent validity, and discriminant validity.
- Can suggest the direction for self-diagnosis, class consulting, and class innovation of teachers who conduct STEAM classes.

Although STEAM education has been rapidly disseminated in schools via government policy support as a new educational model to develop competencies required for future members of society, research has indicated that preparations for the practice of this education are not yet sufficient (Lee & Hwang, 2012; Park, 2012). Studies on the recognition of STEAM education show that teachers demand the provision of various STEAM programs and, though there have been various studies on the development of teaching and learning materials, they have limitations in providing a fundamental basis for effective implementation of STEAM education (Lee et al., 2011; Seoung et al., 2013; Shin & Han, 2011). The dilemma of science, technology, engineering, and mathematics (STEM) education in the United States is that although excellent STEM teachers should have professional knowledge in STEM areas and educational knowledge simultaneously, there are few specific teacher training programs to prepare for these aptitudes (Lee, 2012). In this respect, it is necessary to consider teacher training courses that raise the vocation and sense of duty while developing teacher competency (Shin et al., 2012).

Teaching competency is necessary to enhance professionalism in class; it is defined as an integration of the knowledge, skill, and attitude required for successful implementation of subject matter education (Kim & Lee, 2005; Noh & Choi, 2004; Tigelaar et al., 2004). A review of previous studies on teaching competency shows that evaluation materials on teaching competency have been positively reviewed and that they commonly provide a systematic and detailed plan for diagnosis and enhancement of teaching competency. And yet, even when there is no major difference among classes, identical factors of teaching competency cannot be applied to various educational activities with different learning environments, methods, and subjects.

The role and quality of teachers are very important factors in raising talented leaders of the future. In particular, in a rapidly changing society, effective teaching competency is critical; educating students to meet the requirements of learners has been emphasized more than anything else (Shin et al., 2013). Hence, there have been studies that point out the problems that arise from the changing and expanding standards of teaching competency that a teacher should possess (Park et al., 2013). Although various teacher training programs have been reevaluated with new curricula for effective teaching of STEAM education, most of the programs remain focused on the introduction and utilization of programs, exposing the limitation of their ability to present detailed behavioral indicators for teaching activities. In order for STEAM education to effectively settle in the educational field, exploration and reflection on its educational meaning and practical methodology should be practiced in conjunction with efforts to improve education on a policy level (Park et al., 2012).

Preceding research has suggested a general direction on what STEAM classes are effective in terms of methodology, but has failed to provide a detailed guideline. It is necessary to provide an indicator that checks what must be performed specifically during preparation and implementation for STEAM education. Therefore, plans must be made to strengthen the competency of teachers (which is the prerequisite for success in STEAM education) based on an analysis of how STEAM education is actually conducted in the schools. This study aims to explore and elucidate evaluation indicators of teaching competency for STEAM education. Teachers can use it as a standard to directly assess their own STEAM classes.

BACKGROUND AND THEORETICAL FRAMEWORK

Teaching competency in STEAM education

STEAM education is also called “convergence talent education” in Korea (Park et al., 2012). STEAM grew out of STEM education in some advanced countries such as the United States (Kim, 2012; Park et al., 2012). STEAM education consists of learning experiences that help students realize how to learn and focus by emphasizing logical, mathematical, experimental, and scientific thinking, while increasing students’ learning motivation by arousing their curiosity about mathematic and scientific learning in connection with their real life (Bybee, 2010). This is similar to the direction of Korean STEAM education policies (Na & Kwon, 2014). STEAM education aims to increase students’ science-learning efficacy, confidence, and interest in science in order to motivate them to study science better rather teaching them from concepts in the field of science technology (Baek et al., 2011). Having started to increase students’ understanding of and interest in mathematics and science, STEAM education in Korea is commonly recognized as one of the educational methods that can be used to develop students’ creativity through convergence, realize the goal of creative and character education valued by the present educational curriculum, and foster creativity and convergence talents. STEAM education is an education that helps students have enough convergent literacy to solve various problems in a creative and integrative way by increasing their understanding of and interest in convergent knowledge, processes, and nature in various different fields related to science technology (Kim, 2011; Kim et al., 2011). Since STEAM education pursues the 4C (caring, creativity, communication, and convergence) model, Baek et al. (2011) consider them components of STEAM education and therefore use the name 4C-STEAM.

The ultimate goal of STEAM education is fostering convergence talents, based on the concepts of improving students’ interest, connecting the principles studied with their real life, and enhancing convergent thinking (Park et al., 2012). It is quite similar to Yakman’s (2008) claim that STEAM education makes holistic education possible while putting emphasis on learners’ real life and experiences. Establishing the criteria of learning to accomplish these goals, the framework of STEAM education is comprised of *situation*, *creative design*, and *emotional touch*. Situation is defined learning to feel concretely the necessity of solving problems, creative design encourages students to look for a way of solving problems for themselves, and emotional touch engenders students' enthusiasm for challenging new problems through interest, motivation, and the joy of success. These three elements are the criteria of STEAM learning.

Teaching competency is classified into two areas: theoretical competency and practical competency (Hwang & Baek, 2008). Theoretical competency is defined as the theoretical basis for teachers to successfully perform subject matter education; practical competency is related to teachers' effectively performing subject-matter education in actual classes. Theoretical and practical competency are both further classified into lecture and general competency (Kellough, 1990; Kim, 2014; Yang, 2010). Corbett et al. (2014) proposed 19 types of STEM competences in the domains of contents, skill and ability, instructional practice, and assessment as guidelines for the qualifications of STEM education instructors. In STEAM education, teachers have practical knowledge and high association with pedagogical content knowledge (PCK); could be regarded as the most efficient criteria to explain teachers' knowledge, beliefs, and skills in terms of professionalism in class. In STEAM education, teachers' professionalism can be assessed by elements including content knowledge, curriculum knowledge, teaching method knowledge, learner knowledge, situation knowledge, and assessment knowledge (Kim & Kim, 2013). The domain of content knowledge emphasizes a convergence-type approach to STEAM contents. Furthermore, STEAM contents suggest problem-solving through inquires and design processes as important elements in connecting with real life. In the domain of curriculum knowledge, understanding of the curriculum of STEAM-related subjects and an ability to reorganize are necessary. Teaching method knowledge can be classified by methods that integrate all knowledge about STEAM-related subjects. That is, it contains teaching methods to build up higher-order thinking and creative problem-solving abilities, class strategies to develop STEAM knowledge and students' intentional participation in class. Learner knowledge and the diagnosis of learners' developmental characteristics and behavioral changes are further included. In the domain of situational knowledge, creating a learning atmosphere is one of the main elements of teacher professionalism. Finally, in the domain of assessment knowledge, using various assessment methods for various learning experiences is suggested as one of the main professionalism capabilities of STEAM teachers (Kim & Kim, 2013).

Therefore, of all teaching competencies required by STEAM education, theoretical competency includes subject and curriculum knowledge, teaching design, class methods, assessments, knowledge about learners, etc. Alternatively, practical competency is categorized into creating learning environments, fostering communication, developing professionalism, creating academic stimulations (interaction, motivation, and inducing students' participation, etc.), forming relations with students (acceptance, respect, and affection, etc.), and developing other general features (a sense of humor, leadership, etc.).

METHODOLOGY

As a method to develop teaching competency and verify its validity, we confirmed that the model of teaching competence elements made by both collecting Behavioral Event Interview (BEI) data from the second criteria sample and conducting a literature review could predict the performance of another group performing the same job tasks. In addition, we found it necessary to examine the validity of a competency model by carrying out a test to measure competency defined based on a particular competence model (McLagan, 1977). Development and validation of teaching competency for STEAM education was undertaken in several steps given below.

Literature Review and BEI

To provide evaluation criteria of the teaching competences required for secondary school STEAM education, we applied a literature review and BEIs. In the literature review, we examined competence elements that students should build up as well as target points pursued by STEM/STEAM education. As a method for modeling competence, the BEI aims to supplement competency elements theoretically extracted by collecting empirical data on what STEAM education experts think is most important in STEAM education in actual classes.

Interviews were conducted on four superior-performance teachers and three average-performance teachers of STEAM classes by utilizing Lee's (2009) Situation, Task, Action, and Result (STAR) method. Data were collected in order to evaluate the criteria for teaching competency and indicator modeling by focusing on various cases of activities, their successful experiences, and practical cases. As subjects of these BEIs, we selected teachers who led STEAM class more than three to four times a month, had more than one year's experience in participating in a teachers' research society in a research model school (leader school), and had completed over 60 hours of the relevant training program.

Obtaining expert opinions for assuring content validity

To analyze content validity, 15 experts on STEAM education were selected. The committee of experts was composed of professors, school supervisors who were in charge of STEAM education, master teachers, and ordinary teachers (STEAM leader-school operators, teachers' society operators, and a STEAM education support group from an education office). Verifications were made on the appropriateness of the structural aspect of evaluation areas as well as criteria and contents of evaluation indicators based on the standard of the content validity ratio (CVR).

Pilot testing

After verifying the content validity through this panel of experts, we carried out both the primary and secondary pilot tests on the evaluation criteria for teaching competency in STEAM education for empirical validation. The pilot test was needed in order to modify and supplement evaluation indicators prior to the main survey by finding unsuitable, ambiguous, and low-readability items.

At least 50 samples are required for exploratory factor analysis (Kim, 2010, Kline, 2004). Thus, samples of the first pilot test were given to 55 middle and high school teachers who were participants in STEAM training. They were teachers who actually used STEAM class materials developed with the support of Korea Foundation for Advancement of Science and Creativity (KOFAC) while teaching in leading STEAM-education schools. The participants in the second pilot test were 66 teachers who taught in STEAM leader-schools (one middle school and one high school) and teachers who had applied STEAM education in their classes through the STEAM teachers' society.

Analyses of item quality, reliability, and validity were conducted using two survey questionnaires. To analyze item quality, descriptive statistics such as mean (M), standard deviation (SD), skewness, kurtosis, and degree of correlation were used. For reliability analysis, Cronbach's α coefficient for degree of quality within items was used. Reliability was secured through an elaborate process to delete or modify items with low reliability by confirming values at the time of item elimination. In addition, construct validity of evaluation indicator items was verified through exploratory factor analysis (EFA).

Validating of the Confirmatory Factory Analysis (CFA)

We selected 208 teachers who were currently performing or had performed

STEAM education as subjects for the validation of the developed evaluation indicators. The participants consisted of 97 males (46.6%) and 111 females (53.4%), and the majority of teachers in their 30s (84, 40.4%) or 40s (70, 33.7%). There were 47 science teachers (22.6%), 35 technology teachers (16.8%), 8 engineering teachers (3.8%), 79 arts teachers (38.0%), 20 math teachers (9.6%), and 19 teachers in other fields such as counseling and future career advising (9.1%). The proportion of arts teachers was quite high because all school subjects other than science, technology, engineering, and mathematics were arts subjects, as suggested by Kim (2012). The participants were 66.8% middle school teachers and 33.2% high school teachers. In terms of participation in the STEAM teachers' research society, 65.9% had no experience at all and 34.1% had over 1 year of experience. Seventy-one of the teachers (34.1%) had participated in the pilot research school and 149 (71.6%) had completed over 30 hours of STEAM education-related training.

The revised version of the evaluation indicators of teaching competency, which consisted of 36 items, was administrated in order to run CFA using analysis of moment structure (AMOS) 18 as a confirmatory test of the factorial structure observed in the EFA.

Data analysis

For data collection, questionnaires were created with an on-line program (Survey Monkey) and the link was distributed to subjects via text message or email. To verify the construct validity of the questionnaire survey data, discrimination analysis, Cronbach's α analysis of internal consistency of items, EFA, and CFA were used. SPSS PASW 18.0 was used for correlation analysis, reliability analysis, and EFA and the AMOS 18 program were used for CFA.

RESULTS

Initial form of evaluation indicators using literature review and BEI

Thirty-five evaluation indicators were identified through a literature review on STEAM education and teaching competency; BEIs were then added to another 10 items.

After transcribing the details of BEIs examining four superior STEAM class teachers and four average performing teachers, we analyzed all the behavior events in each evaluation area and their characteristics. In the area of Understanding of Subjects, we found it necessary to suggest class assignments for learners to clearly understand what activities to perform and how to perform them. We further confirmed the characteristics of behavioral events that foster a permissive learning atmosphere between learners. In the area of Understanding of Learners, we found it necessary to know the prior extent to which learners had comprehended and understood the present contents of STEAM-related school subjects and ask proper questions and give feedback for learners to diagnose their understanding and problems during the process of learning. In the area of Learning Environment and Circumstances, we discovered that teachers were developing materials needed for STEAM classes individually or reorganizing the existing teaching materials to fit the specific class circumstances, while carrying out STEAM activities to effectively use the time given in actual class circumstances (Table 1).

Finally, the initial form of evaluation indicators by literature review and BEI consisted of 45 items in six areas: Understanding of Subjects (five items), Design of Teaching Methods and Strategies (17 items), Understanding of Learners (five items), Learning Environment and Circumstances (six items), Evaluation of Learners (six items), and Individual Traits (six items).

Table 1. Summary of superior performing teachers' behavioral events

Area	Behavioral Events of Superior Performing Teachers	Characteristics
A	Tried to understand the content of other subjects related to STEAM to some degree	· Had meeting with teachers of related subjects (e.g., club activities)
	Determined content and timing for learning STEAM-related subjects	
	Explained contents of other subjects in relation to contents of STEAM classes for students' easy comprehension	· Reminded students of the contents learned in other subjects without being bound to the form of STEAM education
	Organized class contents so that contents of related subjects naturally converge	· Developed STEAM program with teachers of related subjects
	Adjusted learning period by realigning curriculum	· Analyzed curriculum of related subjects
B	Primarily focused on motivation and increase of interest in learning	· Applied various interesting factors
	Tried to have students to experience personally rather than through words in order to arouse curiosity	· Placed importance on experiential activities
	Made effort to select exciting class content to attract learners' interest	· Chose interesting subjects
	Aroused learners' interest by linking performed tasks with practical life so that they could participate in class activities	· Induced students to recognize learned tasks as their problems
	Raised questions so that students could discover solutions to problems individually and independently	· Induced students' voluntary learning by raising questions
	Had students apply learned contents in practical life instead of through simple learning activities	· Practiced activities related to practical life
	Applied various teaching methods such as direct experience, discussion, and presentation based on circumstances to enhance the effectiveness of the class	· Applied various methods of teaching
	Created a class atmosphere that allowed for students to consider the problems from various perspectives and express their ideas freely	· Created an accommodating atmosphere
C	Directed students to form groups and allowed members of the groups to choose tasks which fit their levels	· Suggested tasks with diverse levels of difficulty
	Provided hints for solutions and led students to think in different ways by raising questions when they faced a dead end in solving tasks	· Facilitated learning by raising questions
	Continuously raised questions to induce students to think on their own	Induced voluntary learning by raising questions
	Assisted those students who extracted unwanted results after performing assignments achieve success by tracing back the cause of the failure during the process of solving problems	· Provided feedback on the results of learning
D	Asked for assistance in curriculum and class preparation in order to understand curriculum and contents (what is learned when) in other subjects	· Exchanged information with teachers of other subjects
	Organized timely STEAM class contents by considering the basic class progress concurrent with the STEAM classes	· Planned time distribution
	Utilized exhibition models or completed samples related to class contents to help students' understanding	· Prepared various teaching materials related to class
	Examined the overall process of the class to determine possible problematic situations and manufactured outcomes in advance of production activities	· Clarified the process of learning by rehearsing class plans in advance
E	Had difficulty assessing students' creative problem-solving abilities (one of the ultimate goals of STEAM education)	· Conducted descriptive and essay-type assessments on creative ideas
	Had difficulty assessing a fragmented school subject after content-convergent class	· Conducted effective assessments · Applied a way for students to assess themselves
	Had difficulty assessing student performance with school subject-convergent assessment questions in an actual assessment	
	Needed appropriate measures to maintain students' learning motivation as the assessment was not in figures	· Made appropriate reward
F	Should have a correct understanding of what STEAM education consists of	· Had theoretical understanding of STEAM education
	Found it necessary to form rapport in advance in order for students to participate in class voluntarily and actively in an accommodating atmosphere	· Fostered communication between students and teachers

Actively tried to improve communications with the other teachers to exchange information and establish cooperative relations	· Formed fellowship with the other teachers
Invested the necessary time to conduct STEAM education and had a passion for learning new things	· Had passion for learning and self-development
Had a mindset that is open to accepting various opinions about the class	· Was open and had accepting attitude

Note. A = Understanding of Subjects; B = Design of Teaching Methods and Strategies; C = Understanding of Learners; D = Learning Environment and Circumstances; E = Evaluation of Learners; F = Individual Traits

Expert review for contents validity

The result of content validity analysis by our 15 experts showed that CVR values for construction of the six evaluation areas were all over .49, proving their validity. There was an opinion that the term Individual Traits should be modified to Individual Qualification. Examining the results of the content validity analysis on detailed evaluation indicators by criteria, five items with a contents validity ratio of less than .49, which is minimum standard, were eliminated.

Further feedback showed that teachers' feedback ability in the of evaluation results is important in STEAM education, which places importance on the problem-solving process—self-evaluation in which learners analyze their own learning results. This is a valid process in order to reconsider whether the cause of the result is necessary regardless of whether the learning is deemed successful or not. Through consultation with experts, feedback ability in evaluation of results was added, bringing the total to 41 items.

Factor structure of evaluation indicators by pilot tests

Descriptive statistics, reliability, and construct validity of evaluation indicators were reviewed in the first ($n = 55$) and second ($n = 66$) pilot tests. The results of the confirmation of item quality using descriptive statistics analysis such as mean, standard deviation, skewness, kurtosis, and correlation of item-whole showed that the quality of all items was valid based on the standard of Huck and Cormier (1996). Overall Cronbach's α for the first pilot test was .971 (each area $.830 \leqq \alpha \leqq .938$) and three items were identified as needing an increase in value and required modification. Cronbach's α was .940 (each area $.778 \leqq \alpha \leqq .928$) in the reliability analysis of the second pilot test, showing it to be relatively reliable. One item showed a value of less than .30 in the square of multiple correlation (SMC), which means that this item was invalid for the area and was thus deleted.

In the EFA of the first pilot test, the measured value of kaiser-meyer-olkin (KMO) sample appropriateness was analyzed to be .751, which is good for factor analysis. Six factors over the eigenvalue of 1 accounted for 71.022% of the total variance in the participants' responses. The first pilot test focused on elaboration of evaluation indicators rather than a rigorous standard. Eight items which were loaded in other factors different from theoretical classification and three items which hinder reliability were modified; one redundant item was deleted. In the result of EFA on the results of the second pilot test, there were 10 factors, one of which did not satisfy the standard which requires a factor to possess more than three item variables (Zwick & Velicer, 1986). This study extracted six factors with analysis by reducing factors, which explained 63.959% of total variables. In the result of the second pilot test, three items which hindered reliability and one item which was cross-loaded were eliminated.

Validation by main survey

Factor structure of evaluation indicators (EFA)

As the result of descriptive statistical analysis of the main research ($n = 208$), no element hindering item quality was identified. The result of analysis on overall reliability also showed $\alpha = .961$ (each area $.839 \leqq \alpha \leqq .927$), which is a high reliability and values of SMC were mostly over .50 with small, unique variance of evaluation indicators, showing that they were valid evaluation indicators for the related areas.

As the result of EFA, KMO standard adequacy was good (.937) and each factor was composed of items with factor loading of .40. Correlation analysis of 36 evaluation indicator items used in the main survey showed significant correlations among all items on the level of $p < .01$. The review of factor analysis on overall area, however, indicated seven factors unlike the first and second pilot tests. The Design of Teaching Method and Strategy area was thus divided into two factors.

Factor 1, which included five Design of Teaching Methods and Strategies items, had an explanatory power of 42.839%. Because of its relationship with Learning Participation in Class, Factor 1 was named Inducing Learners to Participate in Learning. Factor 2 included eight Design of Teaching Methods and Strategies items and had an explanatory power of 6.211%. Based on its relationship with real instruction, Factor 2 was named Teaching and Learning Methods. Factor 3 included five Learning Environment and Circumstances items. Factor 4 included five Understanding of Subjects items. Factor 5 included four items from the Individual Qualification area and one from Evaluation of Learners. Thus, one item which was cross-loaded was eliminated. Factor 6 included four items from the Evaluation of Learners area. Factor 7 included four items in the area of Understanding of Learners.

Validation of factor structure (CFA)

In order to verify construct validity, CFA was conducted based on the results of main survey. In examining whether an acceptable solution was acquired through the measurement model before evaluation of the goodness of fit of the model, the results of the parameter estimate, standard error, critical ratio, and SMC were confirmed. As the solution of the measurement model was judged to be acceptable, the process of analyzing goodness of fit as the second stage was conducted. $\chi^{2,}$ *CMIN/df, RMSEA, RMR, RFI, IFI, TLI*, and *CFI* indexes were calculated to verify the goodness of fit of the model (see Table 2). The measurement model was modified after checking the residual statistics, modification index, and parameter change. The results of the analysis with modification indices more than the threshold of 10 showed that there were 11 paths in covariance with modification index and parameter change. Because there is a possibility that covariance exists among each item, we connected e8 and e9, e7 and e10, e14 and e17. Figure 1 shows its modification model. Most goodness-of-fit indexes showed results satisfactory to the optimum model standard or the acceptable standard, proving that the measurement model and modification model are suitable.

Using Hair's (2006) and Fornell and Larcker's (1981) formula, this study confirmed construct reliability and average variance extracted (AVE). The AVEs for all the areas were as follows: Understanding of Subjects, .614; Teaching-learning Methods, .655; Inducing Learners to Participate in Learning, .745; Understanding of Learners, .751; Learning Environments and Circumstances, .659; Evaluation of Learners, .672; and Individual Qualification, .763. Since the EVA values for all areas were over .50, they all possess convergent validity. Coefficients of determination (r^2) between each concept were .133-.529 and the minimum value of AVE was analyzed to be smaller than .614. Thus AVE values are greater than each factor's r^2, showing

Table 2. Result of analyzing the model's goodness of fit

Classification	χ^2	*df*	*CMIN/df*	*RMSEA*	*RMR*	*RFI*	*IFI*	*TLI*	*CFI*
Measurement Model Index	958.960	539	1.779	.061	.034	.793	.908	.897	.906
Modification Model Index	910.421	536	1.699	.058	.033	.802	.918	.908	.917

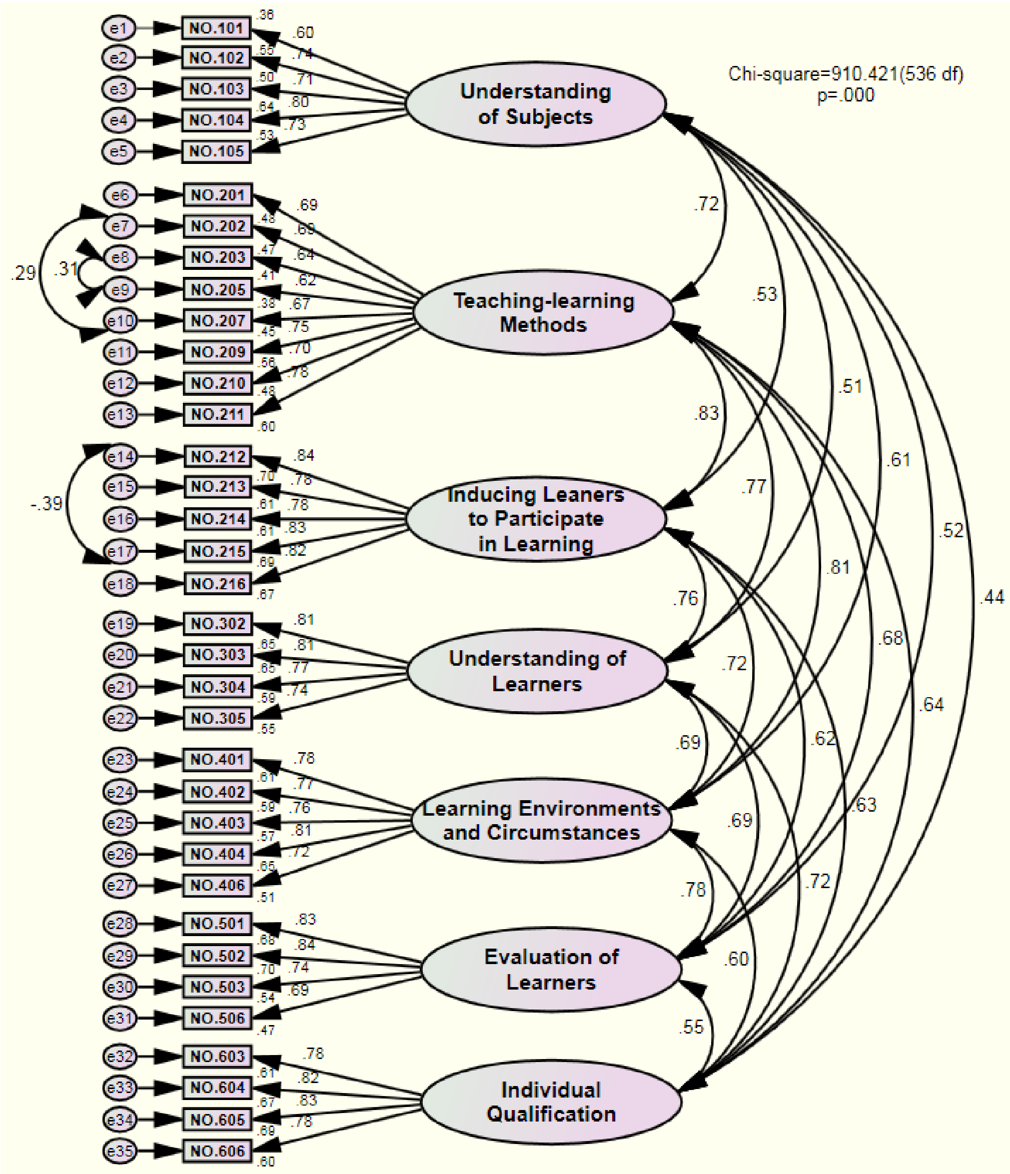

Figure 1. Modification model for CFA using AMOS

that discriminant validity was sufficiently secured.

Final evaluation indicators for teaching competency in STEAM education

The final results of evaluation indicators developed for teaching competency in STEAM education by means of literature review, BEI, and survey research were 35 items in seven areas: Understanding of Subjects, Teaching-Learning Methods, Inducing Learners to Participate in Learning, Understanding of Learners, Learning Environments and Circumstances, Evaluation of Learners, and Individual Qualification, as shown in Table 3.

Table 3. Evaluation ındicators of teaching competency for STEAM Education

Evaluation area	Evaluation indicators	Procedure					
		A	B	C	D	E	F
Understanding of Subjects	Sufficiently understand the curriculum of STEAM-related subjects	○					●
	Analyze and reorganize the related subject curriculum for STEAM classes	○					●
	Clearly understand the contents of the related subjects including STEAM classes	○					●
	Organize the contents of the related subjects so that they can be naturally connected and integrated	○					●
	Properly select important concepts and contents from the other subjects for STEAM classes	○					●
Teaching-Learning Methods	Clearly suggest instructional objectives and contents to learn in terms of convergence	○			M		●
	Arouse students' learning motivation by suggesting concrete situations related to their real lives	○					●
	Provide students with concrete activities related to learning contents, such as experiences and practice	○					●
	Induce defining the problem for oneself	○		–			
	Properly select and use various teaching methods fit for different class contents and situations	○					●
	Instruct based on cooperation with other teachers	○			–		
	Increase students' understanding by concretely explaining and connecting the class contents with their real lives	○					●
	Induce learning procedure through question and feedback	○			–		
	Clearly understand general class contents, such as class assignments and activity processes		+				●
	Induce students to use their STEAM-related knowledge in solving problems	○					●
	Induce all the learners to actively participate in assignment performance activities	○					●
Inducing Learners to Participate in Learning	Clearly guide learners through the class process to create a self-directed learning atmosphere	○					●
	Induce learners to communicate with each other so that they can suggest various opinions	○					●
	Construct an open learning atmosphere for creative problem-solving		+				●
	Stimulate learning activities so that learners may solve problems initiatively	○					●
	Induce performance of assignment through cooperation among learners	○					●
	Connect learning contents through suggestion of advanced assignment	○		–			
Understanding of Learners	Determine the degree of learners' accomplishing assignments and give feedback on a regular basis in class	○			–		
	Check level of assignment completion frequently		+				●
	Diagnose students' learning processes by asking proper questions in class		+				●
	Discover students' misconceptions and hard-conceptions of what they have learned and give them feedback in class activities	○					●
	Constantly determine students' degree of class participation, such as their interest and attitudes, and give them feedback	○			M		●
Learning Environments and Circumstances	Select and use the most effective teaching medium in the process of STEAM classes	○			M		●
	Develop STEAM class materials and reorganize existing class materials individually		+	M	M		●
	Arrange learning space and environments properly by considering students' activities included in STEAM classes	○			M		●
	Properly allocate and manage students' various activities time periods in STEAM classes		+		M		●
	Handle unexpected situations in class		+	–			
	Devise and prepare classes in cooperation with the other teachers teaching other school subjects related to the contents of STEAM classes	○			M		●

Evaluation of Learners	Perform quantitative and qualitative evaluations simultaneously	○					●
	Use various evaluation methods to consider the diversity of learners	○					●
	Assess students' assignment performance process in connection with their academic results	○			M		●
	Offer immanent and external rewards for continuous learning motivation	○		–			
	Evaluate higher order thinking ability (creativity, problem-solving ability, etc.)	○			–		
	Utilize convergent evaluation methods for various subject knowledge		+				●
	Provide feedback from evaluation results			+		–	
Individual Qualification	Believe in and dedicate to STEAM education	○		–			
	Understand the theory and philosophy in STEAM education		+		–		
	Form a basic rapport in sufficient communion with students	○					●
	Have an attitude which opens students' hearts and accepts the opinions of others	○					●
	Have a positive tendency to form cooperation among teachers		+				●
	Continuously self-improves though self-diagnosis and reflection	○					●
	Number of indicators	35	45	41	36	35	35

Note. A: literature review, B: BEI, C: expert review, D: pilot tests, E: main survey, F: final indicators
"+" = additional item, "–" = deleted item, M = modified item

DISCUSSION

The purpose of this study was to develop evaluation indicators for teaching competencies in STEAM education. For this purpose, this study conducted a literature review on general categories of teaching competencies and concepts in STEAM education.

What and how teachers should teach depends on what students should learn, which becomes the very foundation of teaching competencies (Byun & Lee, 2003). Hence, in order to explore teaching competency for STEAM education, this study investigated the competencies which preceding studies on competency in STEM/STEAM education determined that students should develop (Bybee, 2010; Carnevale et al., 2011; Hall, 2014; Park et al., 2012). Competencies categorized in this study include: cognitive ability in subjects (understanding and utilization of convergent knowledge), advanced thinking ability (creativity, problem-solving ability, critical thinking ability, ability to use information, and decision-making ability), ability to contribute to the community (communication ability, ability to engage in social relationships, and cooperative ability), and individual emotional ability (self-respect, positive emotion, considerateness, and civil awareness), which are part of the 4C (creativity, caring, convergence, and communication) as defined by Baek et al. (2012). What differentiates this study from preceding studies, which focused on teaching competency alone, is that this study focuses both on aspects of teaching behaviors of teachers and on enhancement of learning abilities of learners based on the development of learners' competency that STEAM education pursues.

To identify teaching competency in STEAM education, this study classified 35 evaluation indicators in seven areas based on categories of general teaching competency and the concept of STEAM education. Although factors of general teaching competency are classified based on various classification standards such as theoretical competency versus practical competency and lecture competency versus basic competency, they commonly include knowledge of subjects, teaching design, teaching performance, understanding of learners, assessment, creation of learning environments, and individual traits (Hwang & Baek, 2008; Kellough, 1990; Tigelaar et al., 2004). STEAM education includes the learning criteria of situation, creative design, and emotional touch and further includes concepts of increasing students' interest, linkage with practical life, and cultivation of convergent thoughts (Park et al., 2012). Thus, KOFAC (2012) presented a checklist for teachers to determine if their STEAM education was properly conducted. And yet this checklist is limited in that it is confined only to aspects of contents and methods. Creating a learning environment, inducing learner participation, responding based on learners' characteristics, supporting learners' achievement, and developing expertise are also important factors of teaching competency (Jill et al., 1997). By specifically presenting teaching competency in the areas of understanding of learners, creation of a learning environment, assessment of learning, and individual qualification, this study has the potential to be an elaborate standard for self-assessment for STEAM education.

This study drew up six theoretical evaluation areas of teaching competency in STEAM education. Among them, the area Design of Teaching Methods and Strategy was ultimately divided into two areas based on EFA and CFA results. As for STEAM teachers' competency, Corbett et al. (2014) classified competency related to Design of Teaching Methods and Strategies into Skills and Abilities and Instructional Practices. Convergence education, as discussed by Ham et al. (2013), classified this competency as Teaching and Learning Process in terms of practical classes. Although these factors of competency are different in name, they are commonly used in teaching design and development, planning and organization, communication ability, and interaction with students. In particular, communication and interaction with students are factors which are highly regarded in terms of the methodical aspect of STEAM education in which students experience problem-solving processes using various kinds of information rather than learning simply through memorization (KOFAC, 2012). Hence, this study subdivided the teaching competency area Design of Teaching Methods and Strategies into Teaching-Learning Methods and Inducing Learners to Participate in Learning and suggested specific evaluation indicators. In addition, research further classified the study results of Kim and Kim (2013), who suggested Knowledge of Teaching Methods as a professional factor of STEAM education, into communication, creation of a learning environment, learning guidance, and mutual cooperation; this is significant in that it induces learner participation by presenting knowledge in more detail.

In the initial stage of research on teaching competency, most studies conducted a literature review to establish factors of teaching competency but did not reflect the opinions of teachers in the field (Hwang & Baek, 2008; Jin & Na, 2009). Later, some studies utilized the Delphi method to reflect the opinions of teachers in the field (Hwang & Baek, 2008; Lee, 2012). Recently, using competency modeling techniques, there has been a tendency to graft together various inductive materials, such as studies which utilized focus group interviews (FGI) or BEI (Lim & Kim, 2007). This study has further significance in that it described teaching competency by reflecting practical opinions about factors of teaching competency that had been determined theoretically using the competency modeling methods of BEI. The ten items drawn up through BEI were frequently experienced by numerous teachers while conducting STEAM education in practice. In STEAM education, since it is the learners rather than the teachers who take the initiative in learning, it is necessary to induce learners' voluntary and active learning (Park et al., 2012). Hence this study placed importance on teachers' ability to help students clearly understand tasks, create an open learning atmosphere, interact and flexibly respond to the class, and properly assess outcomes. In addition, teachers who practice excellent STEAM teaching laid great stress on the formation of cooperative relationships with teachers of other subjects. Even though general teaching competencies in individual trait areas are diverse, this study was able to determine a practical description of teaching competency which enables effective STEAM education by elucidating factors closely related to STEAM education.

CONCLUSION

Evaluation indicators of teaching competency for secondary school STEAM education were divided into 35 evaluation indicators in seven evaluation areas: Understanding of Subjects, Teaching-Learning Methods, Inducing Learners to Participate in Learning, Understanding of Learners, Learning Environments and Circumstances, Evaluation of Learners, and Individual Qualification. Through the process of determining content validity and construct validity, the authors confirmed that the evaluation indicators developed in this study are valid tools for evaluating teaching competency in STEAM education.

Although teaching competency factors can be elucidated theoretically, it is also necessary to investigate these factors using teachers' varied experience in STEAM education. This study prepared criteria for STEAM education experts and conducted BEI. As this study was considered experiential teaching competency using BEI based on theoretical competency, it suggests field-realistic teaching competency in STEAM classes.

As the evaluation indicators of teaching competency for STEAM education developed by this study are evaluation tools reflecting expertise in STEAM education, they are suitable for evaluation of teaching competency of teachers who perform STEAM education in schools. They can be utilized in education, training, and counseling of teachers for effective practice of STEAM education in the field.

SUGGESTION FOR FURTHER STUDIES

The purpose of this study was to develop evaluation indicators for teaching competency in STEAM education, and it is necessary to prepare detailed evaluation standards that enable further, clear analysis of how well each indicator performs. Further studies to establish detailed standards for diagnosing a STEAM teacher's ability in order to provide clear guidance will enhance the usability of the indicators.

The evaluation indicators of this study are limited in that they did not establish a hierarchy of importance among evaluation areas, criteria, and indicators. Professional studies involving teachers who actually perform STEAM education are required to calculate the weighted values of the evaluation areas, criteria, and indicators. In addition, this study suggests further studies to elaborate and standardize developed evaluation indicators.

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