Using structural equation modelling for understanding relationships influencing the middle school technology teacher's attitudes toward STEAM education in Korea

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Abstract

The purpose of this study was to investigate the structural relationship between technology teachers' attitudes toward STEAM education and the cooperation of instructional resources collaboration, school educational change receptivity, and instructional expertise and instructional efficacy. The population comprised about 3500 technology teachers working in middle schools in Korea, and the sample size was set at 650. Data were collected in parallel with postal surveys and online surveys. A total of 650 copies were distributed, of which 409 were recovered, and 283 copies were used for analysis after data cleaning. The Mplus 7 program was used for data analysis, and the significance level was set at 5%. First, we found that the suitability of the structural model established to clarify technology teachers' attitudes toward STEAM education, instructional resource collaboration, school educational change receptivity, instructional expertise, and instructional efficacy was generally good, so the relationship between the variables was reasonably confirmed. Second, school educational change receptivity and instructional efficacy were found to have a direct effect on attitudes toward STEAM education. Third, the teachers' instructional resources collaboration was confirmed to influence their attitudes toward STEAM education by mediating the school educational change receptivity and instructional efficacy, and their instructional expertise mediated their instructional efficacy. Fourth, school educational change receptivity was confirmed to influence attitudes toward STEAM education through the dual media of instructional expertise and instructional efficacy. Finally, instructional resource collaboration was confirmed to influence attitudes toward STEAM education through school educational change receptivity, instructional expertise, and instructional efficacy.

Keywords Technology teacher · STEAM education · Attitudes toward STEAM education · Structural equation model

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Introduction

As innovations in science and technology and social change continue to accelerate, it is becoming important to bridge divisions in knowledge and technology; thus, there is an increasing need for convergence education such as STEM and STEAM education (Bybee, 2010; Katehi et al., 2009). STEAM education is an educational approach that incorporates the elements of the “arts” into existing STEM education (Yakman, 2006), comprising science, technology, engineering, arts, and mathematics. The emergence of convergence education that includes a focus on technology has served as an important opportunity to secure the status of technology subjects in school (De Vries, 2019). Technology has a highly important role in STEAM education because activities such as design and problem solving, which are important in technology education, are necessary for the integration of different disciplines (Loepp, 2004). For this reason, Yakman (2008) and Sanders (2009) stressed that technology and engineering must be included to ensure the effectiveness of STEM education. However, despite the importance given to technology in STEAM education in Korea, STEAM education is mostly taught by science and math teachers and has been found to be primarily centered on science (Kim & Kim, 2017; Kwak & Ryu, 2016). Alongside the exclusion of technology in the Korean government’s support projects or policies related to STEAM education, technology teachers are likely to feel left out and have a negative perception of STEAM education. Therefore, in order to implement STEAM education more effectively in the future, it is necessary to promote the participation of technology teachers and to change their attitudes toward STEAM education in a more positive direction.

Attitude can be defined as a particular way of responding to an object and is a strong predictor of actual behavior (van Aalderen-Smets & Walma van der Molen, 2015). Therefore, if technology teachers attitudes toward STEAM education become more positive, their actual behavior may also change, thereby improving the success of STEAM education. Further, a structural understanding of the relationship between the major variables that affect such teachers’ attitudes is needed to change teachers’ attitudes toward STEAM education. Most of the researches on the subject of attitudes toward convergence education such as STEAM education in Korea were mainly related to the development of educational programs or teaching materials.

In previous studies, the STEAM education program focused on specific content related to the manufacturing, construction, and information and communication technology, as well as problem-solving learning (Jung & Lee, 2014; Sim et al., 2016) and engineering design process (Kim & Kim, 2014; Lee & Lee, 2014; Lee et al., 2015) mainly designed to understand the technology contents and principles of science and mathematics, and applied them to analyze the effects. However, technology teachers are only focusing on developing programs and materials to apply STEAM education to instructions, little studies have been conducted on attitudes that influence the further promotion of education, or studies on topics such as the relationship between attitudes and related factors and their effects on attitudes. Therefore, it can be seen that the understanding of technology teachers’ attitudes toward STEAM education is insufficient.

There are many variables that affect the attitude of teachers, based on previous studies on attitude, the main variables are collaboration with peer teachers (Stohlmann et al., 2012; Thibaut et al., 2018; Thomas, 2014), receptivity to new educational changes (Thibaut et al., 2018), and improving instructional professionalism (Lee et al., 2014; Al Salami et al., 2017; Gardner et al., 2019; Stohlmann et al., 2012; Thibaut et al., 2018) and educational efficacy (Park et al., 2013; Pryor et al., 2016; Stohlmann et al., 2012). These variables can

also be viewed as major variables affecting the attitudes of technology teachers to STEAM education. In particular, in this study, structural equation modeling was used to analyze the relationship between technology teachers' attitudes toward STEAM education and related variables. It is a combination of the analysis methods of factor analysis and path analysis, and by using this method, it is possible to find out the relationship between variables more accurately by estimating the measurement error of each latent variable. In addition, structural equation modeling is a method to confirm a fitable model based on the relationship between hypothesized variables, and is useful for modeling the structural relationship between attitudes toward STEAM education and related variables.

Therefore, it will be necessary and useful to analyze and understand the structural relationship between technology teachers' attitude toward STEAM education and related variables using structural equation modeling. Accordingly, the purpose of this study was set to investigate the structural relationships among technology teachers' instructional resource collaboration, school educational change receptivity, instructional expertise, instructional efficacy, and attitudes toward STEAM education in middle schools. The results of this study are for researchers in the field of technology education, will help you get a more in-depth understanding such as what variables affect the attitude of technology teachers on STEAM education and the process of forming attitudes toward STEAM education based on the causal relationship between variables. In addition, the main conclusion of the study is expected to be able to help the principals, administrative, and teacher training institutions what kind of support teachers need to effectively promote STEAM education.

Theoretical background

Technology subjects and STEAM education

In Korea, technology as a subject was established as independent subjects in 1969. Since its establishment, the name of the subject has changed alongside revisions of the national curriculum, and it is now called "technology/home economics" (Ministry of Education in Korea, 2015), a common subject for middle schools. The educational objectives of the subject have changed several times due to revisions of the national curriculum, but technological literacy, problem-solving skills, and connection with real life (Yi & Kwak, 2017) have been consistently emphasized. The recently announced 2015 revised national curriculum emphasizes the ability to create new things through the convergence of knowledge, skills, and experiences in various specialized fields based on a wide range of basic knowledge, regardless of the subject (Ministry of Education in Korea, 2015). Accordingly, in order to cultivate students' convergent and creative thinking, the role of teaching that converges various subjects or disciplines is being emphasized. The importance of convergence education was highlighted when the Ministry of Education, Science and Technology (currently the Ministry of Education) in Korea proposed "STEAM education for elementary and secondary schools" as one of the measures to foster science and technology talents in 2011 (Kim, 2011a, 2011b, 2011c). STEAM education is an abbreviation for science, technology, engineering, humanities and arts, and mathematics, and is a new teaching and learning approach that was proposed by Yakman (2006). The abbreviation is distinguished by the inclusion of "A" (arts) in the existing type of STEM education. The term STEM education is more common in the United States, but the term STEAM is primarily used in Korea and has been used in the government's educational policy plan. Sanders (2009) defined STEM

education as an educational approach that explores education and learning between one or more STEM subjects and other subjects, and Yakman (2008) defined STEAM education as interpreting science and technology through engineering, humanities, and arts based on the language of mathematics (p.18).

Technology education has historically played a major role in the integration of different disciplines, as can be seen through integrated educational approaches such as MST (Mathematics, Science, Technology), IMaST (Integrated Mathematics, Science, and Technology Curriculum), and TSM (Technology, Science, Mathematics). MST was initially formulated by science educators as an integrated approach between mathematics, science, and technology education, and has since been actively studied by technology educators (Kim, 2012). Similarly, the IMaST and TSM were first designed and implemented by technology educators to integrate science and mathematics education programs (LaPorte & Sanders, 1996; Satchwell & Leopp, 2002). In another approach, Liao (1998) excluded the relationship between the five main areas of technological literacy, emphasizing the importance of understanding how the concepts of mathematics and science are applied to cultivate technological literacy and analyze technological problems. This approach considers that concrete understanding can be developed by applying the concepts of science and mathematics. In addition, Loep (2004) viewed the activities of technology education, such as the design process, problem solving, and inquiry, as suitable for an integrated context. Thus, technology education can be important for inter-subject integration. In the same context, Clark and Ernst (2007) suggested a technology integration model for education (TIME) model, which is an integrated model centered on technology education, emphasizing the importance of STEM education; Asunda (2012) suggested a connection plan between science and mathematics based on the standard of technological literacy (STL), and proposed that STEM education must be centered on technology education in order to be effective in school education. In addition, De Vries (2019) presented the role and importance of technology education in STEM education in terms of the concept and philosophy of technology. Previous studies have further suggested that the value of technology and engineering needs to be emphasized in STEM (Bybee, 2010; Katehi et al., 2009). In summary, much of the literature indicates that a focus on technology is important in STEM education, which is an integrated approach between subjects, and that technology also plays a major role in STEAM education. In addition, De Vries (2019) proposed that STEM education can be used to overcome the crisis in school curricula related to technology education, while Sanders and Wells (2007) suggested the need for STEM education in technology education.

In previous studies related to the development of STEAM education programs or instructional materials centered on technology subjects in Korea, the technology subjects of STEAM education programs have focused on specific units related to manufacturing technology, construction technology, and information and communication technology (Jung & Lee, 2014) and technology and engineering design processes (Kim & Kim, 2014; Lee et al., 2015). These STEAM education programs have been reported to effectively foster students' problem-solving skills (Sim et al., 2016), technological thinking (Lee & Choi, 2013), and attitudes toward technology (Bae, 2011; Ham et al., 2015; Lee & Lee, 2014) and engineering (Sung & Na, 2012). Although there is no separate training program for STEM teachers in Korea as there is in the United States, it has been confirmed that most technology teachers learn the contents of STEAM education in their teacher training courses. Unlike other subject teachers, most technology teachers have attended a small number of teachers' colleges (Ministry of Education in Korea, 2019), the graduation credits of which ranged from 140 to 150 credits. The curriculum of such colleges is diverse, but they all operate direct and indirect courses on STEM education. Therefore, to effectively

implement STEAM education, it is necessary to integrate different subjects, focusing on the situation or problem through technology education activities. The role of technology must thus be emphasized when STEAM education is implemented in middle schools in Korea. It is predicted that STEAM education will play an important role in enhancing the value and necessity of technology in future schools.

The relationship between attitudes toward STEAM education and instructional resource collaboration, school educational change receptivity, instructional expertise, and instructional efficacy

Attitude is a term that is commonly used to describe a psychological tendency to classify an object as favorable or not—for example, good or bad, pleasant or unpleasant (Ajzen, 1991; Eagly & Chaiken, 1993). In particular, attitude has been found to strongly predict an individual's actual behavior (van Aalderen-Smeets & Walma van der Molen, 2015). Attitudes toward STEAM education are defined as consistent psychological tendencies that determine, based on the definition of general attitudes, whether teachers respond or act in a specific way to teaching a science, technology, engineering, art, and mathematics subject or incorporating such content in their lessons (Allport, 1935). In general, attitude is a multidimensional concept (Zan & Di Martino, 2007) and is widely accepted to comprise three dimensions: affective, cognitive, and behavioral (Eagly & Chaiken, 1993), accordingly, the concept of teachers' attitudes toward STEM or STEAM education can be subdivided into three dimensions. As a specific example, Thibaut et al. (2018) developed a tool that measures attitudes toward STEM education with cognitive, affective, and behavioral recruitment. The cognitive factor refers to the subjective evaluation and belief in an object, the affective factor refers to the feeling or mood, and the behavioral factor refers to the orientation and tendency to act (Asma et al., 2011; Horne, 1985; Zimbarbo & Ebbeseb, 1970). In order for a teacher to implement STEAM education, their intention is important and is directly affected by the teacher's attitude. Teachers' beliefs are considered important for forming positive attitudes toward STEAM education.

Instructional resource collaboration is an activity through which teachers share information, knowledge, and data on instruction among their peer teachers. The relationship between teachers' cooperation and attitudes toward STEAM education indicates that collaboration in instructional resources has a positive effect on STEAM education attitudes. Al Salami et al. (2017) interviewed 29 secondary school teachers in the United States and found that the teachers perceived the difficulty of cooperation between different content areas as one of the obstacles to implementing STEM education. In addition, prior research has shown that the collaborative use of instructional resources such as information, knowledge, and materials related to classes has a positive effect on STEAM education implementation and attitudes toward STEAM education (Fullan, 1982; Park et al., 2017a, 2017b; Schwab & Schwab, 1978). Research conducted by Al Salami et al. (2017) and Celik and Yesilyurt (2013) on the relationship between school educational change receptivity and attitudes toward STEAM education has identified a positive effect of school educational change receptivity on attitudes toward STEAM education. Based on prior studies, such as those of Weiss and Pasley (2006), van Aalderen-Smeets and Walma van der Molen (2015), and Uslu and Bumen (2012) on the relationship between instructional expertise and attitudes toward STEAM education, instructional expertise has a positive effect on attitudes toward STEAM education. In this regard, it has been reported that teachers' efforts to improve instructional expertise

have a positive effect on educational attitudes. In addition, instructional efficacy is based on teachers' expectations and beliefs about their ability to stimulate students' learning motivation in relation to the subject in order to succeed in class, and to use alternative methods or evaluation strategies (Park et al., 2015), based on prior research, it can be seen that the teaching efficacy including the teacher's confidence in the class and the expectation for the result directly and statically affects their attitudes toward STEAM education (Ghaith & Yaghi, 1997; Gorozidis & Papaioannou, 2011; Guskey, 1988; Koballa & Crawley, 1985).

In related studies, collaboration between teachers has been shown to have a direct and static effect on school educational change receptivity (Bae et al., 2014; Elving, 2005; Kim, 2011a, 2011b, 2011c, 2012; Wanberg & Banas, 2000), and it can be seen that school educational change receptivity has a direct and positive effect on attitudes toward STEAM education (Al Salami et al., 2017; Celik & Yesilyurt, 2013). Educational change receptivity directly and positively affects the improvement of instructional expertise (Cho, 2006; Meyer & Herscovitch, 2001), and efforts to improve instructional expertise have a positive effect on attitudes toward STEAM education (Morrison, 2006; Uslu & Bumen, 2012; van Aalderen-Smeets & Walma van der Molen, 2015). In addition, prior studies of the relationship between the improvement of instructional expertise and efficacy indicate that efforts to improve instructional expertise have a positive effect on efficacy (Gardner et al., 2019; Morrison, 2006; van Aalderen-Smeets & Walma van der Molen, 2015) and that instructional efficacy has a direct and static effect on attitudes toward STEAM education (Ashton, 1984; Bandura, 1997; Koballa & Crawley, 1985; Martin et al., 2001). Summarizing the above, it can be seen that school educational change receptivity has a mediating effect on the relationship between teachers' instructional resource collaboration and attitudes toward STEAM education, and school educational change receptivity and instructional expertise can be seen as having a double mediating effect. In addition, it can be inferred that school educational change receptivity, instructional expertise, and efficacy have a triple mediating effect.

The results of studies conducted by Gardner et al. (2019) and Lee and Lee (2019) indicate that instructional efficacy has a mediating effect on the relationship between the enhancement of instructional expertise and attitudes toward STEAM education. In particular, in school education, integration and linkages between subjects have become increasingly important, and in Korea, the revised curriculum for middle and high schools has been applied in 2020, and teachers must develop new capabilities to adapt to these changes. The enhancement of teachers' instructional expertise will be promoted, and their attitudes towards STEAM education, which is one of the new educational changes, can be formed positively through efforts to increase professionalism and instructional expertise. In summary, examining the relationship between school educational change receptivity and attitudes toward STEAM education reveals that the improvement of instructional expertise has a mediating effect, and instructional expertise and efficacy have a double mediating effect.

Further, the collaborative of teachers' instructional resources has been found to directly and statically affect their instructional efficacy (Jo & Na, 2011; Park et al., 2016; Poellhuber et al., 2008). In addition, according to Davis (1989) technology acceptance model, attitudes toward specific technologies are formed by beliefs about the usefulness and ease of use of such technologies, and these beliefs are influenced by external stimuli. At this time, the usefulness can be seen as an expectation for the result, and the ease can be seen as one's confidence that there is no difficulty in using the technology.

Accordingly, teachers' efficacy can directly affect their attitudes toward STEAM education, and their efficacy is influenced by the external stimulus of collaboration in

instructional resources. Thus, instructional efficacy may have a mediating effect on the relationship between instructional resource collaboration and attitudes toward STEAM education. Structural equation modeling, on the other hand, is a useful method to analyze structural relationships between variables, and can confirm whether hypothetical causal relationships between latent variables that cannot be directly measured, including attitudes, are significant (Kim, 2011a, 2011b, 2011c). In particular, by setting a plurality of observed variables including measurement errors, the measurement problem can be solved and path coefficients between latent variables can be more accurately estimated (Kim, 2011a, 2011b, 2011c). Therefore, it can be seen as a suitable method to analyze the structural relationship between teachers' attitudes toward STEAM education, instructional resource collaboration, school educational change receptivity, instructional expertise, and instructional efficacy based on the preceding research on the relationship between variables.

Research methods

Research design

Based on the results of the theoretical background review, a structural relationship research model between technology teachers' instructional resource collaboration, school educational change receptivity, instructional expertise, instructional efficacy, and attitudes toward STEAM education was developed, as shown in Fig. 1.

Figure 1 presents a model of a relationship in which the collaborative use of technology teachers' instructional resources is an exogenous variable; school educational change receptivity, instructional expertise, and instructional efficacy are mediating variables; and attitudes toward STEAM education is an endogenous variable.

The relationship between the latent variables included in the research model was assumed as follows based on previous studies. First, instructional resource collaboration, school educational change receptivity, instructional expertise, and instructional efficacy will have a direct and positive effect on attitudes toward STEAM education (Hypothesis(H)

Fig. 1 Research model of technology teacher's instructional resource collaboration, school educational change receptivity, instructional expertise, instructional efficacy, and attitudes toward STEAM education

1–1, 1–2, 1–3, 1–4). This is based on the following previous studies that on cooperation between teachers and teachers' practice (Kim, 2011a, 2011b, 2011c, 2012; Bae et al., 2014; Elving, 2005; Wanberg & Banas, 2000), acceptance of school education change and teachers' attitudes such as STEM (Al Salami et al., 2017; Celik & Yesilyurt, 2013; Meyer & Herscovich, 2001), the improvement of instructional expertise and educational attitude (Morrison, 2006; Uslu & Bumen, 2012; van Aalderen-Smeets & Walma van der Molen, 2015), and teaching efficacy and teachers' teaching attitude (Ashton, 1984; Bandura, 1997; Koballa & Crawley, 1985; Ghaith & Yaghi, 1997; Gorozidis & Papaioannou, 2011; Guskey, 1988; Martin et al., 2001).

Second, instructional resource collaboration will have a positive effect on attitudes toward STEAM education by mediating instructional efficacy and school educational change receptivity (H 2–1, 2–2). In addition, instructional resource collaboration will have a positive effect on attitudes toward STEAM education through school educational change receptivity and instructional expertise as a double mediation (H 2–3). And instructional resource collaboration will have a positive effect on attitudes toward STEAM education through the triple mediation of school educational change receptivity, instructional expertise, and instructional efficacy (H 2–4). This is based on the following the direct influence relationship between the latent variables presented above and previous studies that cooperation between teachers directly and positively affects the acceptance of changes in school education (Kim, 2011a, 2011b, 2011c, 2012; Bae et al., 2014; Elving, 2005; Wanberg & Banas, 2000), acceptance of changes in school education has a direct and positive effect on the development of class expertise (Cho, 2006; Meyer & Herscovich, 2001), and efforts to enhance instructional professionalism should have a positive effect on teachers' efficacy (Gardner et al., 2019; Lee & Lee, 2019; Morrison, 2006; van Aalderen-Smeets & Walma van der Molen, 2015).

Third, school educational change receptivity will have a positive effect on attitudes toward STEAM education through class expertise (H 2–5). In addition, school educational change receptivity will have a positive effect on STEAM education attitude through the dual mediation of instructional expertise and instructional efficacy (H 2–6). This is based on the following the relationship between the variables presented above and previous studies that Acceptance of changes in school education has a direct and positive effect on the development of class expertise (Cho, 2006; Meyer & Herscovich, 2001), and Efforts to enhance instructional professionalism should have a positive effect on teachers' efficacy (Gardner et al., 2019; Lee & Lee, 2019; Morrison, 2006; van Aalderen-Smeets & Walma van der Molen, 2015).

Finally, instructional expertise will have a positive effect on the attitudes toward STEAM education through the sense of instructional efficacy (H 2–7). This is based on the following presented above previous studies that The relationship between instructional expertise, instructional efficacy, and STEAM education attitude, along with the relationship between instructional professionalism enhancement and teacher efficacy (Gardner et al., 2019; Lee & Lee, 2019; Morrison, 2006; van Aalderen-Smeets & Walma van der Molen, 2015).

In addition, observed variables that can objectively measure each latent variable included in the structural relationship model were established according to the findings of prior studies. Instructional resources collaboration was set as the sharing of student information, subject knowledge, and teaching materials with other teachers based on the study of Hong (2006), Kwon and Kim (2013), Song and Park (2016) and Shah (2011). School educational change receptivity was set as an understanding of changes in curriculum and teaching and learning based on the study of On (2015), Yoon et al. (2017), Park et al., (2017a, 2017b) and Wanberg and Banas (2000). Instructional expertise was set as

the improvement of teaching knowledge and teaching skills based on the study of Shulman (1986). Instructional efficacy was set as confidence and outcome expectations at instruction based on the study of Ashton and Webb (1985), Enochs and Riggs (1990), Gibson and Dembo (1984) and Lee (2009). Finally, attitudes toward STEAM education were set as value judgment, preference, and behavioral orientation for STEAM education based on the study of Eagly and Chaiken (1993) and Thibaut et al. (2018).

Sample for study

The subject of this study is a technology teacher belonging in a middle school in Korea. For the study sample, first, 10 technology teachers were sampled to secure the face validity of the measurement tool for each observed variable.

In addition, 80 technology teachers were sampled for preliminary survey for the reliability test of the measuring tool. In the preliminary survey, the sample size of 30–100 is appropriate, 80 were set in consideration of the non-response and recovery rate. The preliminary survey sample was given to middle schools in Korea with random numbers and randomly selected for technology teachers belonging to the schools.

Finally, for the research model analysis, the sample was selected to represent the population except for the technology teachers who participated in the preliminary survey. The study population was technology teachers who were attend middle schools in Korea in May 2020. In Korea, the subject is characterized as technology/home economics, so although there are separate qualifications for technology and home economics teachers, there are cases where a technology teacher teaches the home economics section or a home economics teacher teaches the technology section. In this study, the subject was set as a teacher who had a technological qualification and were engaged in technology instruction. According to statistics from the Ministry of Education in Korea (2019), as of 2019, there was a total of 3572 teachers of technology/home economics subjects in middle schools (Ministry of Education in Korea, 2019), with 1466 teachers (41.04%) working in metropolitan environments, and 2106 teachers (58.96%) working in provinces. Accordingly, the ratio of middle school technology teachers by school location is similarly 1 (metropolitan city):1.4 (province). The sample size was determined by considering the structural equation model analysis, while ensuring that the population would be represented. In the structural equation model analysis, the sample size is proportional to the number of observed variables, at least 1:10–20, and the appropriate sample size should be at least 200 (Jackson, 2003). Then, since there are a total of 12 observed variables suggested in the structural equation modeling between the technology teacher's attitudes toward STEAM education and related variables, the appropriate sample size was calculated to be 200–240 people. Finally, taking into account the recovery rate of the actual questionnaire, non-response, and unreliable responses, and cases in which respondents had a technology subject certification but were not in charge of technology instruction, the sample size was 650. This was judged to be sufficient to represent the population of technology teachers in Korea (Park, 2003). As for the sampling, the list of middle school technology teachers corresponding to the population could not be obtained, so the list of middle schools was obtained from the government's school information website, and middle schools were extracted using a random check after assigning a serial number to each school by metropolitan city and province. Using the website of the selected school, all technology teachers belonging to the school were sampled and this process was repeated until the number of samples allocated for each ratio

of metropolitan city and province was satisfied. 409 out of 650 responded, and the sample size used to analyze the final research model was 283, excluding insincere responses and outliers.

Instruments

Questionnaires were used as the survey tool for data collection. The questionnaire was composed of observed variables of each latent variable regarding technology teachers' attitudes to STEAM education, instructional resource collaboration, school educational change receptivity, instructional expertise, instructional efficacy, and questions on the demographic characteristics of teachers.

Technology teachers' attitudes toward STEAM education are consistent psychological tendencies (Allport, 1935) that can predict whether teachers will respond or act in a specific way in their teaching of integrated science, technology, engineering, art, and mathematics content. Based on prior studies (Eagly & Chaiken, 1993; Thibaut et al., 2018), observed variables were set as the value judgment, preference, and behavioral propensity for STEAM education. The measurement tool for value judgment was developed by utilizing the attitudes toward STEM measurement items of Wahono and Chang (2019) and the technology teacher's attitude measurement tool used by Xu et al. (2019); the measurement tools of preference and behavioral propensity were attitudes toward STEM measurement items of Wahono and Chang (2019), attitudes toward STEM education measurement items of Thibaut et al. (2018), and the attitude measurement tool of Xu et al. (2019).

Instructional resource collaboration is a collaborative activity in which teachers share information about students, subjects, and materials with fellow teachers in order to provide successful instruction (Shah, 2011). The observed variables were drawn from prior studies (Hong, 2006; Kwon & Kim, 2013; Shah, 2011; Song & Park, 2016) and were set as sharing student information, subject knowledge, and teaching data. The measurement tool for the sharing of student information was developed by using Shah (2011) teacher's idea and expertise sharing measurement questions, and the measurement tool for the sharing of subject knowledge was developed by utilizing the questions from Shah (2011) teacher's idea and expertise sharing measurement, and Song and Park (2016) teaching expertise-oriented teacher cooperation activities measurement. The measurement tool for the sharing of instruction materials was developed by utilizing the questions developed by Shah (2011) and Song and Park (2016).

School educational change receptivity refers to a teacher's belief in changes in the curriculum, teaching, and learning occurring in the school field, and their will to actively accept and implement such changes (Bae et al., 2014). The observed variables were set as understanding changes in the curriculum and changes in teaching and learning. The measuring tool for understanding curriculum change was developed based on the questionnaire for measuring the receptivity of school innovation used by Lee (2012), and a measurement tool for understanding teaching and learning change was developed based on prior studies (On, 2015; Park et al., 2017a, 2017b; Wanberg & Banas, 2000; Yoon et al., 2017).

Instructional expertise is a teacher's ability to improve their instruction-related expertise (Kim & Hong, 2018), which is divided into content knowledge, pedagogical knowledge, and pedagogical content knowledge, according to the concept suggested by Shulman (1986). Pedagogical content knowledge not only refers to knowing theory or content, but also practical knowledge that can be applied to classes (Shulman, 1986) and knowledge developed through an actual class (Loughran et al., 2006). Based on these results,

the observed variables were set to improve instructional knowledge and skills. The measures used to improve instructional knowledge and instructional skills were developed using prior studies on instructional expertise and related knowledge (Grossman, 1990; Shulman, 1986; Tamir, 1988, etc.) and Ahn's (2005) questions on teachers' self-development efforts.

Lastly, instructional efficacy refers to the confidence teachers' confidence that they can do well, and their expectations and beliefs about the results that can be obtained through instruction (Enochs & Riggs, 1990; Gibson & Dembo, 1984; Park et al., 2015). Based on prior studies (Ashton & Webb, 1985; Enoch & Riggs, 1990; Gibson & Dembo, 1984; Lee, 2009), the observed variable was set as the confidence and outcome expectation in the instruction. As a measurement tool of confidence and outcome expectation, the items on the subcategory of the science teaching efficacy measurement tool of Enoch and Riggs (1990) were modified and utilized.

For the above measurement tools, content validity and face validity were verified. The content validity was verified by three professors in the Department of Technology Education, considering whether the item content of the measurement tool for each observed variable was appropriate and whether the technology teacher's responses were inadequate or difficult to understand. We reviewed whether there were any problems, and ten technology teachers for the verification of face validity were reviewed to see if there was any difficulty in their understanding and responses to the contents of the question. Based on the review results of experts and teachers, the composition of the overall questionnaire was revised so that the measurement tools for each observed variable could be clearly identified, and the contents of some measurement questions were revised and supplemented.

In addition, the Cronbach's α was calculated to confirm the reliability of the measurement tool, and the reliability test results are shown in Table 1.

A preliminary survey for reliability test was conducted from April 25–30, and 80 technology teachers were targeted. The results of the 61 responses were used. Cronbach's α was calculated from the preliminary survey data, and according to the criteria suggested by Nunnally (1978), it was generally confirmed that the Cronbach's α for the measurement

Table 1 Reliability analysis results for measurement tools

Latent variable	Observed variable	Cronbach's α	
		Preliminary survey (n = 80)	Main survey (n = 283)
Attitudes toward STEAM education	Value judgment	0.937	0.980
	Preference	0.874	0.883
	Behavioral propensity	0.953	0.972
Instructional resources collaboration	Student information	0.838	0.965
	Subject knowledge	0.869	0.922
	Teaching materials	0.871	0.961
School educational change receptivity	Curriculum changes	0.885	0.900
	Teaching and learning changes	0.905	0.939
Instructional expertise	Improvement of teaching knowledge	0.732	0.939
	Improvement of teaching skill	0.714	0.917
Instructional efficacy	Confidence	0.665	0.898
	Outcome expectation	0.856	0.952

item was 0.70 or higher, and was used in the main survey. In the main survey conducted after that, it was judged that reliability was secured as all of them were above 0.70.

Finally, confirmatory factor analysis was conducted to confirm the convergent validity of the measurement tool. In the confirmatory factor analysis, as the factor rotation method, geomin rotation (Yates, 1987) which is a orthogonal rotation, and the number of iteration was 1000. According to the analysis results, as for the measurement items for each observed variable of the latent variable, the estimated factor load was $\beta=0.517\text{--}0.879$, mostly 0.5 or more, which was found to have a statistically significant value (Woo, 2012). However, for the two items measuring preference among the observed variables of the latent variable attitudes toward STEAM education, the factor load estimates were less than 0.5 ($p < 0.01$) with $\beta=0.162$ and $\beta=0.209$. 'STEAM education is mediocre,' and 'STEAM education is difficult.' It was judged as inappropriate and deleted from the final analysis. In addition, among the measurement items for each observed variable of instructional efficacy, the three items measuring confidence had factor load estimates of $\beta=0.304$, $\beta=0.383$, and $\beta=0.462$, which were less than 0.5 ($p < 0.01$). were all negative questions and were judged to not have validity, so they were deleted from the final analysis.

The composition of the items in the questionnaire finally used for the survey is shown in Table 2. The questionnaire consisted of a total of 66 items, including those asking about demographic characteristics.

Data collection and analysis

Data collection was conducted using postal surveys, and online surveys were also conducted when necessary. The questionnaire comprehensively considers the rate of recovery, non-response, and unfaithful responses, and cases in which the current teacher did not conduct instruction in the field of technology, and 650 copies were distributed. For the survey,

Table 2 Composition of questionnaires

Latent variable	Observed variable	Item number	Number of items
Attitudes toward STEAM education	Value judgment	I.1–1)–6)	6
	Preference	I.2–1), 2), 3)*, 4)	4
	Behavioral propensity	I.3–1)–6)	6
Instructional resources collaboration	Student information	II.1–1)–4)	4
	Subject knowledge	II.2–1)–4)	4
	Teaching materials	II.3–1)–4)	4
School educational change receptivity	Curriculum changes	III.1–1)–5)	5
	Teaching and learning changes	III.2–1)–5)	5
Instructional expertise	Improvement of teaching knowledge	IV.1–1)–5)	5
	Improvement of teaching skill	IV.2–1)–5)	5
Instructional efficacy	Confidence	V.1–1), 2), 3), 4)	4
	Outcome expectation	V.2–1)–7)	7
Demographic characteristics		VI-1–7	7
Total			66

*Negative questions

a list of technology teachers was identified through information on the status of faculty members by referring to the website of the selected target school, and questionnaires were distributed individually by mail by referring to the address of the affiliated school. Teachers who responded to the questionnaires were rewarded a mount of 4 USD.

In order to increase the data collection rate, teachers who did not collect the questionnaire 10 days after distribution of the questionnaire were contacted to encourage their participation, and teachers who had difficulty sending mail were asked to participate by submitting the questionnaire online. In addition, the survey URL was distributed using the social network system community of the Korea Technology Teachers' Association, and it was added to the analysis data by checking whether it matched the pre-set sample based on the school name of the teachers participating in the survey. Data collection was conducted from May 11 to June 5, 2020; 409 of the total 650 questionnaires distributed were collected (recovery rate: 62.9%), and 15 of the collected questionnaires were excluded due to a lack of a response regarding qualifications, 82 copies of questionnaires answered by teachers who did not have qualifications (78 copies) or who had qualifications but were not in charge of technology subject instruction (4 copies) were excluded. In addition, among the response results, consecutive checks of the same number for each page were judged as unfaithful responses (7 copies) and excluded, based on the average value for each item, the response value (14 copies) that deviated from the standard deviation $[\pm 2]$ distribution was judged as an outlier. The Mahalanobis distance value was derived based on the measured value of each observed variable, and the statistically significant ($p < 0.001$) value (8 copies) was judged as an outlier (Kline, 2011) and excluded. Accordingly, the data of 283 copies (valid data rate: $283/409 \times 100\% = 69.2\%$) excluding 126 copies were used for analysis. The distribution ratio of the location of the school to which the final technical teacher responded was about 1.1:1 in the metropolitan city (48.4%) and provinces (51.6%), which was similar to the distribution ratio of the population (1:1.4). It was confirmed that there was no bias according to gender, age, and years of experience, so it was judged that implying that the findings from the data can be generalized to the population.

Data analysis was conducted using SPSS 23.0 for Windows and Mplus 7 programs. Using SPSS 23.0 for Windows program, Box plot, reliability of measurement items (Cronbach's alpha), Mardia multivariate kurtosis, descriptive statistics and correlation analysis by observed variables, and multicollinearity diagnosis analysis were performed. Using the Mplus 7 program, the Mahalanobis distance, average variance extracted (AVE), confirmatory factor analysis, and structural equation model analysis were performed. In all analyses, the statistical significance level (α -level) was set at 0.05. To confirm whether the analysis data were suitable for the structural equation model analysis, the multivariate normality of the observed variable was verified, and a significance test for the Mardia multivariate kurtosis index was performed. However, since multivariate normality can be confirmed by examining the univariate normality of each variable (Kline, 2011), the normality was finally determined by considering this together, and univariate normality did not exceed |3| if the kurtosis did not exceed |10|, normality was considered to be secured (Kline, 2011). The correlation coefficient between the observed variables was statistically significant ($p < 0.05$), and the correlation coefficient was confirmed to be less than 0.8 (2005), and the appropriateness of the analysis data was reviewed. It was confirmed that the tolerance was greater than 0.1, and the variance inflation factor (VIF) was less than 10 (Kim, 2011a, 2011b, 2011c). Although there is no exact criterion for good fit, prior studies have empirically determined that a CFI of 0.90 or more is appropriate, an RMSEA of less than 0.05 is a good close fit, and an RMSEA of less than 0.08 is a reasonable fit. If it is greater than 0.10, it is judged as a bad model, and if the SRMR is less than 0.08, it is judged as

suitable (Kim, 2011a, 2011b, 2011c). Since the χ^2 value is very sensitive to the sample size, it is considered inappropriate to judge that the model is not suitable only on this basis (Kline, 2011). Convergent and discriminant validity were checked to examine whether the observed variables set in the model properly measured the latent variables. In the confirmatory factor analysis, the rectangular rotation method, geomin rotation (Yates, 1987), was used, and when the factor load estimate was 0.5 or more and it was a statistically significant value, it was judged that convergent validity was secured (Woo, 2012). Discriminant validity was confirmed using three methods. First, it was confirmed whether the square value of the correlation coefficient between latent variables was less than the mean average variance extraction (AVE) value (Fornell & Larcker, 1981), which is the most stringent method, and second, for the latent variable, it was checked whether the interval of ± 2 standard error of the correlation coefficient between variables did not include 1 (Woo, 2012). Finally, a non-constrained model with free correlation between the latent variables and the covariance between the two latent variables was controlled at 1. It was confirmed whether there was a significant difference (≥ 3.84 or more in the χ^2 value between the constraint models when the change in degrees of freedom (df) was 1 (Bae, 2014; Woo, 2012). To confirm the direct effect, a t-test was performed using the critical ratio, and the mediating effect was confirmed by using Sobel's method (delta method) provided by Mplus 7 since it was determined that the sample size was sufficient.

Result and discussion

Descriptive statistics and measurement model fit of observed variables for each latent variable

Table 3 shows the descriptive statistics and normality analysis results of the observed variables concerning technology teacher's attitudes toward STEAM education, instructional resource collaboration, school education change receptivity, instructional expertise, and instructional efficacy in middle schools.

The average value of observed variables for each latent variable of middle school technology teachers was 3.64–4.33, which is generally understood as a positive level. The average value of the observed variables of the latent variable attitudes toward STEAM education was highest in the order of value judgment ($M=4.33$), preference ($M=4.07$), and behavioral propensity ($M=4.00$). The highest was in the order of sharing teaching material ($M=3.76$) and subject knowledge ($M=3.64$). The average value of each observed variable of the school education change receptivity latent variable was highest in the order of applying teaching and learning change ($M=4.25$) and understanding of curriculum change ($M=3.95$). The average value of each observed variable of the instructional expertise latent variable was highest in the order of improvement of teaching knowledge ($M=4.26$) and improvement of teaching skills ($M=4.14$). Finally, the average value of each observed variable of the latent variable of instructional efficacy was highest in the order of confidence in instruction ($M=4.03$) and outcome expectation ($M=3.82$). The Mardia multivariate kurtosis index of these observed variables was statistically significant (Mardia kurtosis = 193.319, $p < 0.001$), indicating that normality was not secured. However, univariate normality was in the range of -1.791 to -0.380 for skewness and 0.184 – 6.624 for kurtosis, and the normality conditions required to apply the maximum likelihood method in structural equation model analysis (skewness $< |3|$, kurtosis $< |10|$) were found to be satisfied

Table 3 Descriptive statistics and normality analysis results of observed variables for each latent variable related to the technology teacher's attitudes toward STEAM education

Latent variable	Observed variable	Min	Max	M	S.D	Skewness	Kurtosis
Attitudes toward STEAM education	Value judgment (6)	1.00	5.00	4.33	0.593	-1.791	6.624
	Preference (4)	1.25	5.00	4.07	0.599	-1.165	3.494
Instructional resources collaboration	Behavioral propensity (6)	1.00	5.00	4.00	0.670	-1.009	2.602
	Student information (4)	1.25	5.00	4.16	0.673	-0.819	1.363
	Subject knowledge (4)	1.00	5.00	3.64	0.771	-0.576	0.413
	Teaching materials (4)	1.00	5.00	3.76	0.848	-0.561	0.184
School educational change receptivity	Curriculum changes (5)	1.60	5.00	3.95	0.606	-0.380	0.700
	Teaching and learning changes (5)	1.80	5.00	4.25	0.594	-0.954	1.287
Instructional expertise	Improvement of teaching knowledge (5)	1.40	5.00	4.26	0.547	-0.717	1.832
	Improvement of teaching skill (5)	1.80	5.00	4.14	0.563	-0.474	0.479
Instructional efficacy	Confidence (4)	1.75	5.00	4.03	0.609	-0.619	0.712
	Outcome expectation (7)	1.43	5.00	3.82	0.615	-0.801	1.774
Multivariate normality(Mardia's test)							193.319***

N (total number of responses) = 283

*** $p < 0.001$

(Kline, 2011), so it can be judged that there was assumptions about normality of data hold valid. On the other hand, kurtosis of the value judgment variable was 6.624, which was higher than that of other observed variables. As the degree of peakedness of the data, kurtosis is used as an indicator to examine the normal distribution, and it was judged that there is no significant problem with the corresponding variable according to the criteria presented by Kline (2011).

Table 4 shows the correlations between the observed variables used in technology teachers' attitudes toward the STEAM education structure model in middle schools. The correlation coefficients between the observed variables were all statistically significant ($p < 0.01$), and the correlation coefficient between the observed variables of each latent variable was generally larger than that of the observed variables of other latent variables, but other latent variables were observed. Since the value of the correlation coefficient with the variable does not exceed 0.8 (Hong, 2006), it can be judged that it is appropriate for analyzing the relationship between the latent variables. However, in the case of instructional efficacy, the correlation between the observed variables of other latent variables was higher than the correlation between the observed variables within the corresponding latent variable; therefore, it is necessary to be careful in interpreting the relationship between instructional efficacy and other latent variables when analyzing the structural model. The tolerance of the observed variables for each latent variable was 0.333–0.763, all of which are 0.1 or more, and the VIF value was 1.310–3.001, which is less than 10 (Kim, 2011a, 2011b, 2011c), confirming that there was no multicollinearity problem.

Figure 2 shows the results of the confirmatory factor analysis conducted to determine the fit of the measurement model of the latent variables and observed variables introduced in the technology teacher's attitudes toward the STEAM education structure equation model of middle schools.

As mentioned in the fit criterion of the structural equation model, the χ^2 value of the measurement model was statistically significant ($\chi^2 = 119.796$, $df = 44$, $p < 0.001$), but the rest of the fit index CFI was 0.964, RMSEA was 0.078, and SRMR was 0.040, which satisfied all criteria (Kim, 2011a, 2011b, 2011c), making it possible to judge this as a fitted model indirectly measuring each latent variable. According to Fig. 2, the factor load estimate, standard error, and p value are presented together, and the factor load of the first index variable of each factor is fixed at 1. Table 5 shows the results of the analyses of the factor loadings of observed variables for each latent variable in order to verify convergent validity for the observed variables composed of each latent variable included in the technology teachers' attitudes toward the STEAM education structure equation model of the middle school accurately measure the concept. It was judged that the convergent validity was secured (Woo, 2012) because the factor loading amount (0.644–0.893) of the observed variables for each latent variable was more than 0.5, showing a statistically significant value.

Table 6 shows the results of the analysis of the correlation coefficient between the latent variables to confirm the discriminant validity of the instructional resources collaboration, school education change receptivity, instructional expertise, instructional efficacy, and attitudes toward STEAM education. The correlation coefficient between all latent variables was statistically significant ($p < 0.001$), and the value was found to be between 0.492 and 0.899. Regarding discriminant validity, the higher the correlation coefficient value, the higher the probability that the validity will decrease; therefore, the one with the highest correlation between the latent variables was selected to verify whether the square value of the correlation coefficient between the latent variables was less than the AVE value.

Table 4 Correlation coefficient between observed variables for each latent variable related to technology teachers' attitudes toward STEAM education

Latent variable	Observed variable	1	2	3	4	5	6	7	8	9	10	11	12
Attitudes toward STEAM education	Value judgment	1											
	Preference	0.783**	1										
	Behavioral propensity	0.707**	0.687**	1									
Instructional resources collaboration	Student information	0.485**	0.478**	0.494**	1								
	Subject knowledge	0.422**	0.422**	0.452**	0.625**	1							
	Teaching materials	0.391**	0.356**	0.428**	0.604**	0.759**	1						
School educational change receptivity	Curriculum changes	0.534**	0.506**	0.578**	0.489**	0.468**	0.458**	1					
	Teaching and learning changes	0.585**	0.540**	0.536**	0.537**	0.478**	0.483**	0.710**	1				
	Improvement of teaching knowledge	0.582**	0.544**	0.630**	0.552**	0.523**	0.518**	0.671**	0.672**	1			
Instructional expertise	Improvement of teaching skill	0.506**	0.487**	0.626**	0.588**	0.530**	0.565**	0.667**	0.677**	0.784**	1		
	Confidence	0.509**	0.485**	0.496**	0.537**	0.487**	0.411**	0.467**	0.518**	0.597**	0.594**	1	
	Outcome expectation	0.553**	0.422**	0.480**	0.399**	0.360**	0.402**	0.403**	0.438**	0.423**	0.478**	0.487**	1

** $p < 0.01$

Fig. 2 Results of the analysis of the measurement model of technology teachers' attitudes toward STEAM education, instructional resources collaboration, school educational change receptivity, instructional expertise, and instructional efficacy. *** $p < 0.001$. The values presented refer to the coefficient and the standardized coefficient. $\chi^2 = 119.796$, $df = 44$, $p < 0.001$

Table 5 Factor loading of observed variables for each latent variable related to technology teachers' attitudes toward STEAM education

Latent variable	Observed variable	B	β	S.E	t
Attitudes toward STEAM education	Value judgment	1.000	0.893	0.018	49.254***
	Preference	0.967	0.855	0.021	41.595***
	Behavioral propensity	1.029	0.813	0.025	32.616***
Instructional Resources Collaboration	Student information	1.000	0.750	0.032	23.463***
	Subject knowledge	1.317	0.863	0.022	38.435***
	Teaching materials	1.423	0.847	0.023	36.207***
School educational change receptivity	Curriculum changes	1.000	0.833	0.024	34.319***
	Teaching and learning changes	1.004	0.852	0.023	36.880***
Instructional expertise	Improvement of teaching knowledge	1.000	0.882	0.018	47.764***
	Improvement of teaching skill	1.036	0.888	0.018	49.184***
Instructional efficacy	Confidence	1.000	0.756	0.039	19.214***
	Outcome expectation	0.860	0.644	0.043	14.918***

*** $p < 0.001$

Table 6 Correlation coefficient and AVE value among latent variables related to technology teacher's attitudes toward STEAM education

Latent variable	Attitudes toward STEAM education	Instructional resources collaboration	School educational change receptivity	Instructional expertise	Instructional efficacy
Attitudes toward STEAM education	0.725				
Instructional resources collaboration	0.595***	0.686			
School educational change receptivity	0.755***	0.685***	0.710		
Instructional expertise	0.726***	0.734***	0.899***	0.783	
Instructional efficacy	0.808***	0.735***	0.776***	0.856***	0.492

The diagonal number represents the AVE value of each latent variable

*** $p < 0.001$

The highest correlation coefficient value was the correlation coefficient between instructional expertise and school educational change receptivity ($r=0.899$, $p<0.001$). The squared value of the correlation coefficient was 0.808, and the AVE value of instructional expertise was 0.783. In addition, the AVE value of school educational change receptivity was 0.710, indicating that the two AVE values were less than the square value of the correlation coefficient, which did not meet the criteria for securing the corresponding discriminant validity (Fornell & Larcker, 1981).

However, according to the result of confirming the discriminant validity with the correlation coefficient and SE value between latent variables, the standard error of the correlation coefficient between instructional expertise and school education change receptivity was found to be 0.025, and the interval of the correlation coefficient ± 2 standard error was $0.849-0.949$ ($=0.899 \pm 2 \times 0.025$); thus it was confirmed that the discriminant validity was secured because 1 was not included.

Finally, a non-constrained model and a controlled constrained model that did not control the correlation between instructional expertise and school education change receptivity with the highest correlation coefficient were set, and the discriminant validity was confirmed through χ^2 verification between them (see Table 7).

The χ^2 value of the non-constrained model that did not control the correlation between instructional expertise and school education change receptivity was 131.114 ($df=48$), and the χ^2 value of the constrained model that controlled the correlation between the two latent variables was 152.274 ($df=49$), the $\Delta\chi^2$ value ($\Delta df=1$) was 21.260 ($p<0.001$), which was confirmed to have a significant difference of 3.84 or more (Bae, 2014; Woo, 2012); and finally, it was judged to have secured discriminant validity.

The relationship model of technology teachers' attitudes toward STEAM education

Figure 3 shows the relationship between the latent variables of technology teachers' attitudes toward STEAM education, instructional resource collaboration, school education change receptivity, instructional expertise, and instructional efficacy in middle schools.

As previously suggested in the criteria for determining the fitness of the structural equation model, the χ^2 value of the structural relationship model was statistically significant ($\chi^2=129.030$, $df=46$, $p<0.001$), but the remaining fitness indices, CFI=0.961, RMSEA=.080, SRMR=0.042, all of which meet the criteria for judgment (Kim, 2011a, 2011b, 2011c), can be judged as a fit for verifying the causal relationship between latent variables.

In Fig. 3, a complete line means a statistically significant path coefficient, a dotted line means an insignificant path coefficient, and a number means a coefficient and the standardized coefficient. As a result, this relationship model was adopted and could be established between technology teachers' attitudes toward STEAM education, instructional resource collaboration, school educational change receptivity, instructional expertise, and instructional efficacy. However, the path coefficients leading to attitudes toward

Table 7 Result of verifying χ^2 value between non-constrained model and constrained model

Division	χ^2	df	$\Delta\chi^2$
Non-constrained model	131.114	48	21.260***
Constrained model	152.274	49	

*** $p<0.001$

Fig. 3 Results of the analysis of the structural relationship model of technology teachers' attitudes toward STEAM education, instructional resources collaboration, school educational change receptivity, instructional expertise, and instructional efficacy. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$. The values presented refer to the coefficient and the standardized coefficient.) $\chi^2 = 129.030$ ($df = 46$, $p < 0.001$)

STEAM education in the instructional resources collaboration and instructional expertise were not significant; thus, hypothesis 1–1, 1–3, 2–3, and 2–5 were rejected.

However, the relationship between instructional resources collaboration and instructional expertise and attitudes toward STEAM education, which was established based on the results of prior studies, was found not to be statistically significant. This can be seen as a result of the large degree of influence of school education change receptivity, which was set to affect the attitudes toward STEAM education due to the characteristics of the structural equation model analysis, and therefore, instructional resource collaboration and instructional expertise. It is necessary to be careful in interpreting the results of the study that it does not have an effect.

The final modified model is shown in Fig. 4; when compared with the hypothetical research model, the χ^2 value was similarly statistically significant ($\chi^2 = 131.571$, $df = 48$, $p < 0.001$), but the remaining fitness indices, CFI = 0.961, RMSEA = 0.078, SRMR = 0.042, which satisfy the criteria for judgment (Kim, 2011a, 2011b, 2011c), and the RMSEA index, which considers the simplicity of the model, decreased from 0.080 to 0.078. Among the fitness indices in the revised model, RMSEA was changed to a more suitable one. RMSEA is an index that evaluates the approximate fit of a model, according to the criteria of Browne and Cudeck (1992), 0.08 means a mediocre fit, and 0.78 means a fair fit, which is interpreted as being modified to a more suitable model.

According to the modified structural relationship model (Fig. 4), instructional resources collaboration has a direct positive effect on instructional efficacy and school educational change receptivity, and instructional expertise has a direct positive effect on instructional efficacy. Also, school educational change receptivity and instructional efficacy have a direct and positive effect on attitudes toward STEAM education. Instructional resources collaboration indirectly positively affects attitudes toward STEAM education through instructional efficacy as a mediate and school educational change receptivity as a mediate.

Fig. 4 Modified structural relationship model of technology teachers' attitudes toward STEAM education, instructional resources collaboration, school educational change receptivity, instructional expertise, and instructional efficacy

Direct effect of school education change receptivity and instructional efficacy

Table 8 shows the results of the analysis of the direct effects of school education change receptivity and instructional efficacy on teachers' attitudes toward STEAM education according to the established model.

It was found that the technology teachers' school education change receptivity ($\beta = 0.398$, $p < 0.01$) had a direct and static positive effect on their attitudes toward STEAM education. This indicates that when the school education change receptivity increases by one standard deviation, the attitudes toward STEAM education increases by 0.398 standard deviation; thus, hypothesis 1–2 that school education change receptivity has a direct and static effect on the attitudes toward STEAM education is adopted.

Further, it was found that technology teachers' instructional efficacy ($\beta = 0.496$, $p < 0.001$) had a direct and static positive effect on the attitudes toward STEAM education. This indicates that when the instructional efficacy increased by 1 standard deviation, the attitudes toward STEAM education had a standard deviation of 0.496. Therefore, hypothesis 1–4 was adopted such that instructional efficacy had a direct and static positive effect on teachers' attitudes toward STEAM education. Relatively, it was confirmed that the effect

Table 8 Results of the analysis of the direct effects of school education change receptivity and instructional efficacy on technology teachers' attitudes toward STEAM education of technology teacher

Path	<i>B</i>	β	<i>S.E</i>	<i>t</i>
School educational change receptivity → Attitudes toward steam education	0.410	0.398	0.114	3.496***
Instructional efficacy → Attitudes toward STEAM education	0.677	0.496	0.118	34.204***

*** $p < 0.001$

of technology teachers' instructional efficacy on attitudes toward STEAM education was greater than that of school education change receptivity.

Mediating effect of school education change receptivity, instructional expertise, and instructional efficacy

Table 9 shows the results of the analysis of the mediating effect of school education change receptivity, instructional expertise, and instructional efficacy on teachers' attitudes toward STEAM education.

It was found that the relationship between instructional resource collaboration and attitudes toward STEAM education, it was confirmed that instructional efficacy ($\beta=0.133$, $p<0.01$) had a significant positive static mediating effect. This means that when the instructional resource collaboration increases by one standard deviation, the attitudes toward STEAM education increases by 0.133 ($=0.269 \times 0.496$) standard deviation by mediating instructional efficacy while controlling for other variables. Therefore, hypothesis 2–1 was adopted such that the instructional resources collaboration will indirectly and positively affect the attitudes toward STEAM education through instructional efficacy.

Likewise, the technology teacher's school education change receptivity ($\beta=0.291$, $p<0.01$) had a significant static positive mediating effect on the relationship between instructional resource collaboration and attitudes toward STEAM education. This means that when the instructional resource collaboration increases by one standard deviation, the attitudes toward STEAM education increases by 0.291 ($=0.731 \times 0.398$) standard deviation by mediating school education change receptivity while controlling for other variables. Accordingly, hypothesis 2–2 was adopted such that the instructional resources collaboration would indirectly and positively affect the attitudes toward STEAM education through school education change receptivity.

It was found that acceptance of school education changed receptivity, instructional expertise, and instructional efficacy positively mediated the relationship between instructional resource collaboration and attitudes toward STEAM education ($\beta=0.206$, $p<0.01$). This means that when the instructional resource collaboration increases by one standard deviation, the attitudes toward STEAM education is 0.206 ($=0.731 \times 0.928 \times 0.613 \times 0.496$) standard deviation by mediating the threefold positive mediating of school education change receptivity, instructional expertise, and instructional efficacy while controlling for other variables. Therefore, hypothesis 2–4 was also adopted such that the instructional resources collaboration indirectly and statically positive affect the attitudes toward STEAM education through threefold mediation of school education change receptivity, instructional expertise, and instructional efficacy.

And, we found that instructional expertise and instructional efficacy positively mediated the relationship between school education change receptivity and attitudes toward STEAM education ($\beta=0.282$, $p<0.01$). This means that when the school education change receptivity increases by one standard deviation, the attitudes toward STEAM education increases by 0.282 ($=0.928 \times 0.613 \times 0.496$) standard deviation by mediating the instructional expertise and instructional efficacy in a controlled state of other variables. Therefore, hypothesis 2–6 were also adopted.

Finally, in the relationship between instructional expertise and attitudes toward STEAM education, it was confirmed that instructional efficacy ($\beta=0.304$, $p<0.01$) had a significant positive static mediating effect. This means that when instructional expertise increased by one standard deviation, the attitudes toward STEAM education increased by

Table 9 Results of the analysis of the mediating effects of school education change receptivity, instructional expertise, and instructional efficacy on technology teachers' attitudes toward STEAM education of technology teachers

Path	<i>B</i>	β	<i>S.E</i>	<i>t</i>
Instructional resources collaboration → Instructional efficacy → Attitudes toward STEAM education	0.136	0.133	0.052	2.545**
Instructional resources collaboration → School educational change receptivity → Attitudes toward STEAM education	0.296	0.291	0.085	3.425**
Instructional resources collaboration → School educational change receptivity → Instructional expertise → Instructional efficacy → Attitudes toward STEAM education	0.210	0.206	0.065	3.186**
School educational change receptivity → Instructional expertise → Instructional efficacy → Attitudes toward STEAM education	0.290	0.282	0.087	3.230**
Instructional expertise → Instructional efficacy → Attitudes toward STEAM education	0.320	0.304	0.094	3.237**

** $p < 0.01$

0.304 ($=0.613 \times 0.496$) standard deviation by mediating instructional efficacy in the state that controlled for other variables. Therefore, hypothesis 2–7 was also adopted such that instructional expertise would indirectly and positively affect attitudes toward STEAM education through instructional efficacy.

Based on the direct and indirect effects of each of these latent variables, the analysis results of the total effect of technology teachers' instructional resources collaboration, school education change receptivity, instructional expertise, and instructional efficacy on attitudes toward STEAM education are shown in Table 10.

Technology teacher's instructional resources collaboration ($\beta=0.642$, $p<0.001$), school education change receptivity ($\beta=0.680$, $p<0.001$), instructional expertise ($\beta=0.304$, $p<0.01$) and instructional efficacy ($\beta=0.496$, $p<0.001$) positively affects the attitudes toward STEAM education, both directly and indirectly, and it was confirmed that the school education change receptivity and instructional resources collaboration had a greater effect than others. In addition, technology teachers' school education change receptivity and instructional efficacy can be seen as the main factors that directly and indirectly influence the positive attitudes toward STEAM education, and have an receptive to new changes in school education, therefore, in particular, it can be seen that it will be important to have confidence and positive outcome expectations for the instruction.

Discussion and limitations on the research results

The measurement model of the latent variables related to the technology teacher's attitudes toward STEAM educational and the structural relationship model between the latent variables were confirmed to be valid. In addition, the convergent validity and discriminant validity of the measurement model also satisfy each criterion, so it is judged that it is reasonable to measure each latent variable with the set observed variables. In other words, the technology teacher's attitudes toward STEAM education can be measured by value judgment, preference and behavioral propensity toward STEAM education, instructional resources collaboration can be measured by student information, subject knowledge and teaching materials, and school educational change receptivity can be measured by understanding curriculum changes and changes in teaching and learning. And, instructional expertise can be measured by improvement of teaching knowledge and improvement of teaching skill, and instructional efficacy can be measured by confidence in instruction and outcome expectation.

Table 10 Results of the analysis of the total effects of instructional resources collaboration, school education change receptivity, instructional expertise and instructional efficacy on attitudes toward STEAM education of technology teachers

Path	Direct (β)	Indirect (β)	Total (β)
Instructional resources collaboration → Attitudes toward STEAM education	–	0.642***	0.642***
School educational change receptivity → Attitudes toward STEAM education	0.398***	0.282**	0.680***
Instructional expertise → Attitudes toward STEAM education	–	0.304**	0.304**
Instructional efficacy → Attitudes toward STEAM education	0.496***	–	0.496***

** $p<0.01$, *** $p<0.001$

However, among the latent variables, the correlation coefficient between school educational change receptivity and instructional expertise was found to be slightly higher than 0.8, and the AVE value of instructional efficacy was slightly lower as 0.492, so the discriminant validity was interpreted with caution. Nevertheless, the criterion was satisfied based on whether the correlation coefficient between latent variables and the ± 2 standard error interval included 1, and it was confirmed that the χ^2 verification result between the non-constrained model and the controlled constrained model also satisfies the criterion for discriminant validity. Conceptually, it can be seen that discriminant validity is secured as the school educational change receptivity, instructional expertise and other latent variables are clearly distinguished.

Meanwhile, the χ^2 value, CFI, RMSEA, and SRMR indices were used to determine the fitability of the measurement model and the structural relationship model. Among them, the χ^2 value was statistically significant (measurement model: $\chi^2 = 119.796$, $df = 44$, $p < .001$, structural model: $\chi^2 = 129.030$, $df = 46$, $p < 0.001$) did not meet the criteria for judgment. The χ^2 test tests the null hypothesis that there is no difference between the data implemented through the model and the data of the population. In addition, it is necessary to comprehensively consider other goodness-of-fit indices because there is a limit to being affected by the sample size at the same time (Hong, 2000; Kline, 2011). Therefore, it is not appropriate to judge that the model is not fitable just because the χ^2 value does not meet the criterion, ultimately, it would be appropriate to judge the model as a fitted model. Nevertheless, it was confirmed that the relationship between instructional resources collaboration and instructional expertise, which was established based on the results of previous studies, and attitudes toward STEAM education was not statistically significant. In addition, when examining the relationship between instructional resources collaboration and instructional expertise and attitudes toward STEAM education based on the correlation between the latent variables, it was found that there is a correlation between them. This can also be seen as a result of the large degree of influence of school educational change receptivity and instructional efficacy, which were set as affecting attitudes toward STEAM education due to the characteristics of structural equation model analysis, and thus, instructional resources collaboration and instructional expertise are affected. It is necessary to pay attention to the interpretation of the study results.

Conclusions

The conclusions of this study are as follows. First, a fitted structural relationship model can be established between the exogenous variable of the technology teacher's instructional resources collaboration, the mediating variable of the technology teacher's school educational change receptivity, instructional expertise, and instructional efficacy, and the endogenous variable of attitudes toward STEAM education. It can be inferred that this relationship model reflects the typical teacher culture in middle schools in Korea, where there is a significant amount of shared collaboration with fellow teachers on instruction. There is much opportunity for receptivity changes in school education, while focusing on the subject-oriented instructional expertise, and instructional efficacy will soon increase and affect teachers' attitudes toward STEAM education. Although the structural relationship model requires more sophisticated proof through further research, it can be concluded that technology teachers' instructional resource collaboration, school educational change

receptivity, instructional expertise, and instructional efficiency are all directly and indirectly related to their attitudes toward STEAM education.

Second, technology teachers' school educational change receptivity and instructional efficacy have a direct positive effect on their attitudes toward STEAM education, and the effect of instructional efficacy has a greater effect than school educational change receptivity. However, instructional resource collaboration and instructional expertise indirectly positively affect school education change receptivity, instructional expertise, or instructional efficacy by mediating without directly affecting it. Therefore, in order to enhance technology teachers' attitudes toward STEAM education, it is necessary to first promote the level of instructional efficacy or receptivity changes in school education. In addition, in order to ensure technology teachers' receptivity changes in school education and to enhance their effectiveness, both collaboration in instructional resources and promotion of instructional expertise should simultaneously be considered.

Third, technology teachers' instructional resource collaboration does not directly affect their attitudes toward STEAM education, but has an indirect positive effect by mediating school education change receptivity, instructional expertise, or instructional efficacy. The size of the single-media effect through school educational change receptivity in instructional resources collaboration is twice as large as the single-media effect through instructional efficacy. Instruction resource collaboration indirectly affects school educational change receptivity, the triple mediating of instructional expertise and instructional efficacy, which generally tends to decrease as the number of mediating variables increases.

Fourth, technology teachers' school educational change receptivity directly positively affects their attitudes toward STEAM education, and indirectly by double-mediating instructional expertise and instructional efficacy. However, this was not affected by instructional expertise. Therefore, the relationship between school educational change receptivity, instructional expertise, instructional efficacy, and attitudes toward STEAM education suggests that it may be effective to consider receptivity changes in school education first, but to deal with instructional expertise together if emphasis is placed on instructional efficacy.

Fifth, technology teachers' instructional expertise has an indirect positive effect through instructional efficacy, although it does not directly affect the attitudes toward STEAM education, and its size is more than twice the impact of the instructional resources collaboration on instructional efficacy. This suggests that it is a more effective approach for enhancing instructional expertise together, rather than simply dealing with instructional efficacy in enhancing teachers' attitudes toward STEAM education.

Implications

The results of this study can be used to make the following implications. First, the relationship model for technology teachers' attitudes toward STEAM education can be used to select strategies to understand and enhance middle school technology teachers' attitudes toward STEAM education. Further, the structural equation model can be used under the theme of technology teachers' attitudes toward STEAM education in the future as a basic theoretical basis model for further research, such as research on the relationship between variables.

Second, it is necessary to prioritize changing technology teachers' receptivity to school education to enhance their attitudes toward STEAM education and to consider instructional resource collaboration or instructional expertise together as a strategy to enhance the

indirect rather than the direct effect of instructional efficacy. Technology teachers' school educational change receptivity has been confirmed to have the greatest direct effect on the positive formation of attitudes toward STEAM education, and instructional efficacy has been found to be more effective through instruction resource cooperation and instructional expertise than through direct effects, which should be considered when implementing support policies or projects for STEAM education for actual technology teachers.

Third, technology teachers' instructional resource collaboration, including attitudes toward STEAM education, school educational change receptivity, and the setting of observed variables by latent variables for instructional expertise and instructional efficacy have generally been found to be reasonable and thus applicable in further research. In particular, technology teachers' attitudes toward STEAM education could be set apart in cognitive, affective, and behavioral dimensions, and it would be possible to apply it to study the relationship between STEAM educational attitudes and other latent variables. However, there was a high correlation problem between some observed variables, and it would be necessary to be careful to resolve the multicollinearity problem by lowering the correlation between the observed variables.

Fourth, in future studies, it will be necessary to approach the questions and measures of the measurement tools, which are observed variables by the latent variables of instructional expertise, in terms of attitudes toward STEAM education. In particular, instruction resource collaboration and instructional expertise latent variables have been developed to measure the frequency of instruction resource exchange activities or the degree of effort activities for instructional expertise, and further studies are needed to develop the level of observed variables directly.

Fifth, according to the relationship model of attitude toward STEAM education confirmed through this study, it is necessary to conduct research on the subject of attitude toward STEAM education of general teachers such as science and mathematics as well as technology teachers. These follow-up studies may give useful implications in implementing integrated STEAM education with other subject teachers.

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