Lai, C.-L. (2021). Exploring Taiwanese Teachers' Preferences for STEM Teaching in Relation to Their Perceptions of STEM Learning. *Educational Technology & Society*, *24* (4), 123–135.

Exploring Taiwanese Teachers' Preferences for STEM Teaching in Relation to their Perceptions of STEM Learning

Chiu-Lin Lai
Department of Education, National Taipei University of Education, Taiwan // jolen761002@gmail.com

ABSTRACT: Educators believe that STEM activities allow students to use multiple skills to solve real-world problems; therefore, it has been recognized as an effective way to apply academic knowledge to life's problems. While many studies have examined the effectiveness and perceptions of students' learning through STEM activities, little research has been conducted on teachers' perceptions of STEM activities. In particular, there has been little research on teachers' preferences for STEM learning. Therefore, in this study, two questionnaires were employed to investigate the teachers' preferences for and perceptions of STEM learning and teaching. The questionnaire of teachers' preferences for STEM learning consisted of four scales, namely, activity flexibility, technology support, classroom interaction and teaching assistance, while the questionnaire of perceptions of STEM learning included higher order thinking, collaboration, and attitude toward STEM learning. A total of 307 teachers from 25 high schools in Taiwan filled in the questionnaire after conducting STEM activities. From the result of structural equation modeling it was found that teachers' perception of collaboration was the key element connecting the teachers' preference for STEM activities and attitude toward STEM learning. In addition, the teachers' preference for technical support and classroom interaction positively correlated with their perceptions of higher order thinking and collaboration, while activity flexibility and teaching assistance positively correlated with their attitude toward STEM learning. According to the results, it was found that teachers' perceptions of STEM learning were pluralistic and differed according to their preferences.

Keywords: STEM education, Teacher professional development, Teaching preference, Attitude toward STEM education

1. Introduction

In recent years, STEM education has been recognized as an important educational issue (Wahono et al., 2020). In general, STEM education refers to integrating the disciplines and skills of science, technology, mathematics, and engineering. It has placed great emphasis on students' practical skills, and has developed their competitive ability to face complex problems through hands-on experience in the process (Chang & Chen, 2020). According to the results of a literature analysis based on Wahono et al. (2020), STEM activities can also motivate students to progress to a higher level of thinking, which in turn affects their academic performance. Researchers believe that STEM education is well suited for developing soft skills such as problem solving, higher order thinking, and collaborative communication skills (Lin et al., 2020).

Much of the research has practiced the spirit of STEM, guiding students to integrate and apply concepts from science, mathematics, technology, and engineering to solve problems themselves (Century et al., 2020; Kelley et al., 2020). For example, Hu et al. (2020) investigated the impact of using the Knowledge, Skills, and Attitudes (KSA) instructional mode on students' learning effectiveness when making an electronic musical pencil. The results showed that the use of the KSA mode can positively enhance students' attitudes towards STEM, and improve their learning outcomes. Besides, some studies investigated the effectiveness of technology on students' hands-on activities. Altmeyer et al. (2020) developed a tablet-based AR application to support hands-on experimentation in physics science. It was found that the students could gain more conceptual knowledge through effective technological assistance. Although the integration of technology and content is necessary, the role of the teacher in STEM learning may also be an important factor in determining the quality of the learning outcomes (Dong et al., 2020). In Lin's et al. (2020) research, they explored the role of teachers in teaching and learning in a web-based collaborative problem-solving system (wCPSS) learning environment. According to their results, even if the e-learning system benefits students' STEM problem solving, if the teachers do not provide guidance during the learning process, it is still hard to highlight the effectiveness of students' STEM learning.

Researchers are also interested in teachers' perceptions of STEM education, research has shown that teachers' attitudes are a key aspect of successful teaching and learning (Wu & Albion, 2019; Yeh & Tseng, 2019). Adov et al. (2020) explored STEM teachers' attitudes toward using mobile devices for teaching, and investigated what factors might help to increase teachers' willingness to conduct STEM activities. The results of the questionnaire analysis showed that teachers' expectations and effort expectancy of activities were highly correlated to the teachers' attitude toward using mobile technology. Affouneh et al. (2020) also explored teachers' perceptions of professional development in STEM teaching and learning. The factors that teachers perceived as influencing their STEM professional development included the availability of teaching resources, teachers' professional competence and beliefs, and the operation of the teacher community. As Gosling and Moon (2002) stated, the teacher's expectations of the teaching objectives and outcomes would determine the effectiveness of student learning in the process. Therefore, it is important to explore teachers' perspectives on that approach to teaching and learning.

However, teachers face many challenges when developing STEM activities (Wahono & Chang, 2019). For example, they may be unfamiliar with how to connect different curricula, they may not understand effective assessment methods for STEM outcomes, and there may be few exemplars to emulate (Brand, 2020). The reasons for these difficulties stem from a number of external factors including restricted classroom environments, limitations of the curriculum framework, and inadequate teaching resources. Therefore, researchers have pointed out that teachers' preferences need to be considered (Chuang & Tsai, 2005), since they determine the teachers' needs from several external perspectives (e.g., technology needs, environmental needs, and content needs). In the meantime, an investigation exploring the relationship between these external perspectives and internal perspectives (e.g., attitudes) is needed (Angel-Alvarado et al., 2020). Without overall consideration of teachers' internal and external needs, it is likely to result in unsuccessful curricula, which might reduce the opportunity for students to practice solving complex problems (Kelley et al., 2020). Therefore, to effectively encourage teachers to develop STEM activities, educators and school managers need to understand the teachers' considerations and preferences for conducting STEM activities.

The purpose of this study was, therefore, to investigate the teachers' perspectives on STEM learning by examining their preferences for and perceptions of STEM learning. This study examined the contextual preferences of teachers when conducting STEM activities. Meanwhile, we also investigated how these preferences are related to the teachers' perceptions of STEM learning. In this way, school managers and teachers can develop meaningful STEM teaching activities based on the teachers' preferences.

2. Literature review

2.1. Learning outcomes of STEM activities

Learning outcomes are often used as a reference to measure the effectiveness of a learning approach (Beege et al., 2020). Students' perceptions and cognitive development of the learning process are usually reflected in the learning outcomes (Cedefop, 2017). At the same time, learning outcomes are also a reference basis for teachers' teaching quality; teachers' expectations of students' learning outcomes can also be reflected in their teaching effectiveness (Kong et al., 2020; Song & Hwang, 2020).

In the field of STEM education research, in addition to students' learning achievement, researchers are more concerned about the development of students' higher level skills (Simeon et al., 2020). This is because STEM emphasizes not only effective knowledge application, but also problem solving, teamwork, and critical thinking in the process (Kong et al., 2014). Two important skills that the researchers have identified as important for students are higher order thinking skills and collaboration (Wahono et al., 2020).

Higher order thinking has been recognized as a concept of education reform based on Bloom's taxonomy (Hu et al., 2020). It involves cognitive processing such as analysis, evaluation, and synthesis (Bloom et al., 1956). It is believed that higher order thinking skills play a very important role in knowledge acquisition in students' STEM activities. For instance, Yu et al. (2020) examined the influence of students' scientific knowledge and higher order thinking tendency on their design of engineering projects. The results showed that the students' higher order thinking ability (e.g., deduce, explain, and evaluate) was an important ability when they attempted to apply scientific knowledge during the design process. On the other hand, Wahono et al. (2020) reviewed 54 STEM studies and found that effective STEM activities begin with encouraging students' higher order thinking, then move to their academic achievement, and end with students' motivation.

On the other hand, collaboration is considered to be an important competitive skill (Wang et al., 2020). It is related to the ability of learners to integrate into a group of people or to communicate effectively once they enter the community (Patten et al., 2006). Researchers have also stated that the design of STEM instructional activities that consist of collaboration and communication can enhance the development of students' skills (Lou et al., 2014). Many studies have found that doing projects is a successful way to stimulate students to conduct collaboration and communication activities (Mustafa et al., 2016; Siew et al., 2015).

From the aforementioned literature, it was known that the instructional strategies and the development of activities have a great potential to help students develop higher order thinking and collaboration skills (Martín-Páez et al., 2019). However, not all teachers who implement STEM activities know how to design STEM activities and incorporate instructional strategies (Martín-Páez et al., 2019). If the outcome of the implementation is the intended goal, teachers need to devote a great deal of effort and time to designing the curriculum (Kelley et al., 2020). This is because such an approach is very different from the past; some external factors have influenced the teachers' identification of STEM learning. Therefore, understanding teachers' perspectives on STEM education and their perceived potential of students' learning outcomes in STEM activities needs to be taken seriously.

2.2. Preference of STEM activities

The integration of technology and instructional strategies into teaching has been recognized as a critical issue (Ogbuanya & Efuwape, 2018). How teaching resources and contexts adapt to learning needs to be reconsidered when introducing new modes or activities (Sandholtz & Ringstaff, 2020). It requires consideration of teachers' basic technological knowledge and pedagogical expertise (Wei, 2020; Ng & Chan, 2021). Mishra and Koehler (2006) proposed three components of the learning environment: content, pedagogy, and technology; these three components would interact and influence each other. In the case of STEM education, it was found that many projects are still limited to technology-oriented projects, such as robotics education and programming education (Lin et al., 2020). This indicated that there may be more barriers than content, pedagogy, and technology, which may be related to teachers' preferences or perceptions (Okumus et al., 2016). As Ertmer (2005) and McElearney et al. (2019) suggested, investigating teachers' perceptions and preferences may be a way to provide important references for teacher professional development.

Preference has been considered as a crucial foundation for the further development of learning environments (Chuang & Tsai, 2005; Franquesa-Soler et al., 2019). Researchers have frequently investigated teachers' and learners' preferences in various learning contexts, such as conventional learning environments, web-based learning environments, and mobile learning contexts (Hwang et al., 2018; Liu, 2020). For instance, Liang and Tsai (2008) explored college students' preferences in Internet-based learning environments. According to their investigation, they found that the students with high Internet self-efficacy presented higher preference for Internet-based learning environments, such as exploring real-life problems, displaying multiple sources of information, and conducting open-ended inquiry activities. Li et al. (2019) examined pre-service teachers' preferences for smart learning contexts. Their results revealed that connectedness was positively associated with all smart classroom features, such as inquiry learning, student negotiation, multiple sources, usefulness, and ease of use. Those studies not only pointed out the factors that need to be considered when developing or conducting activities, but revealed the importance of considering preferences when designing activities or implementation of certain policies.

For the development of STEM activities, researchers have also discussed teachers' preference for STEM education. For instance, Gardner and Tillotson (2020) interviewed a teacher who developed STEM activities, and identified three important factors that the teacher considered. The first was the flexibility of the activities and spaces. The second was the replicability of the instructional models, which indicated the low technical threshold of the curriculum, making it easy for teachers to imitate. The last one was the improvement of teaching deficiencies, indicating that strong teacher teams and administrative support were needed. Through interviews, El Nagdi and Roehrig (2020) also found that STEM teachers valued the level of team support in the curriculum design process; they cited this as a factor that motivated them to develop the curriculum. Wang et al. (2020) also noted that teaching goals and collaboration structure were highly associated with the successful STEM mode.

According to previous studies (Gale et al., 2020; Kelley et al., 2020), the factors that teachers considered when designing STEM instructional activities included activity flexibility, technology support, classroom interaction, and teaching assistance. Activity flexibility refers to the contexts that allow the teacher to have more flexibility in their learning activities. Good flexibility not only allows teachers to create meaningful learning activities, but also enhances the interaction between teachers and students (El Nagdi et al., 2018). At the same time, the flexible curriculum allows teachers to design cross-curricular activities. Technology support refers to the teachers' technology need for conducting learning activities. In particular, in STEM learning environments, learning activities are often complex and lengthy; students or teachers often need technology for recording, communicating, and searching for information (Holmlund et al., 2018). On the other hand, teachers also have expectations about the level of classroom interaction in the activities. This refers to peer discussion or interaction between teachers and students in learning activities (El Nagdi et al., 2018; Stehle & Peters-Burton, 2019). In STEM activities, in addition to the wealth of information, peer cooperation, competition, or communication is also a key factor reflected in the success of instructional activities. In addition to the three influencing factors of learning, technology, and interpersonal interaction, many researchers have recently found that the level of support from the school also affected whether teachers developed their instructional activities (Siew et al., 2019). Therefore, teaching assistance is also important when considering teachers' preferences for instructional activities.

How teachers perceive and what they expect from learning activities also affect the development of the whole activity (Dong et al., 2020; Kelley et al., 2020). Many researchers have taken into account students' preferences for learning patterns and their propensity to perform well (Wahono et al., 2020). Teachers' perceptions of and preferences for instructional modes also affect students' learning and the quality of instruction. Therefore, it is also important and urgent to explore teachers' preferences for and perceptions of the implementation of STEM activities. Therefore, in this study, a survey exploring teachers' preferences for and perceptions of STEM activities was administered. The research questions explored in this study were as follows:

- What are the teachers' preferences for STEM activities?
- What are the teachers' perceptions of STEM activities?
- What is the relationship between teachers' preferences for and perceptions of STEM activities?
- What are the direct and indirect indicators in the model of teachers' preferences for and perceptions of STEM activities?

3. Theoretical framework

In this study, an investigation of teachers' preferences for and perceptions of STEM activities was conducted. To answer the research questions, the research mode was developed based on previous studies' suggestions, as shown in Figure 1.

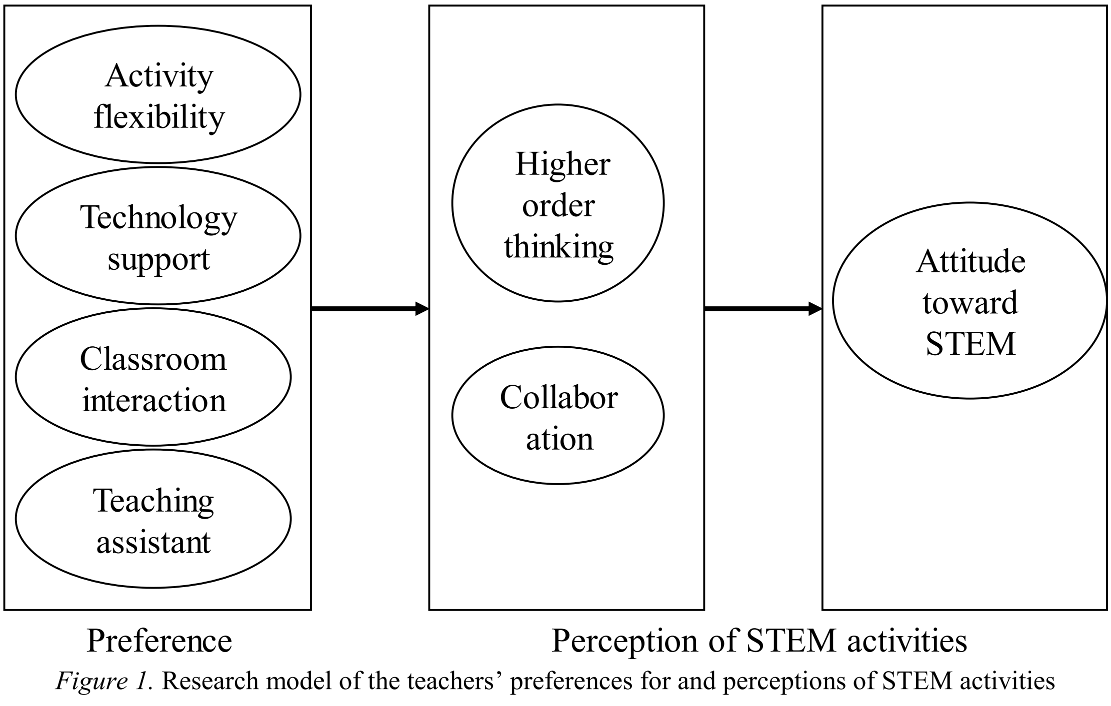

Figure 1. Research model of the teachers' preferences for and perceptions of STEM activities

Many researchers have argued that individual preferences in the teaching and learning process affect learning and teaching outcomes, and that contexts that allow users to engage in relevant activities can be effective (Lin et al., 2019; Liu, 2020). Therefore, two elements were considered in the study: preferences and perceptions. Preferences indicate the teachers' preferences for STEM activities, while perceptions refer to the teachers' perceptions of the effectiveness of STEM activities. As previous studies have suggested (Gale et al., 2020), the factors included in the teachers' preferences for STEM activities consisted of activity flexibility, technology support, classroom interaction, and teaching assistance. On the other hand, the factors included in the teachers' perceptions of STEM activities were higher order thinking, collaboration, and attitude toward STEM activities.

Researchers have also noted that preference for teaching or learning is positively related to learning outcomes (Brand, 2020). By understanding teaching and learning preferences, the learners' or teachers' perceptions of learning can be enhanced, for instance, preferences for technology and students' interaction have been found to be highly related to students' performance of higher order thinking and collaboration (El Nagdi et al., 2018; Holmlund et al., 2018). In addition, the perceptions of learning or teaching were positively correlated to their attitude toward learning or teaching (Wang et al., 2020).

4. Method

4.1. Participants

In this study, an investigation of teachers' preferences for and perceptions of STEM activities was conducted. The teachers who participated in this study had to meet two criteria: (1) they had all conducted mobile technology-assisted learning in the classroom. The mobile learning training was based on the mobile learning training model proposed by Hwang et al. (2017) and Garet et al. (2001); and (2) They all had basic concepts of STEM education or had already conducted STEM activities in the classroom.

To ensure that the activities implemented by the teachers were in line with STEM education principles, the study provided six training workshops and eight regular meetings, as shown in Figure 2. Each session averaged about 2.5 hours, with an average of 50 teachers attending each session. In the training workshops, the study explained the definition of STEM education and teaching examples to help the teachers understand the teaching goals of STEM teaching. The sources of these STEM teaching examples were drawn from the teaching examples of mobile technology-assisted STEM education designed by Hwang et al. (2020); these teaching plans were provided to teachers to help them design distinctive and pedagogically meaningful STEM teaching activities. In the training workshops, this study also guided teachers to co-develop STEM teaching activities. The researcher proposed several educational topics (e.g., using VR for STEM education or developing STEM activities related to environmental conservation), and experienced STEM teachers led teachers without STEM teaching experience to co-create teaching plans. This helped teachers understand the meaning of STEM education and curriculum development methods.

Regular meetings were also arranged to provide teachers with the opportunity to adjust the quality of their teaching. The study invited all participating teachers to physical meetings, and invited experts experienced in promoting STEM and technology-enhanced learning to attend. In addition to teaching experience sharing, the teachers were invited to share the problems they met during the teaching activities, and the experts provided them with practical help. Therefore, through this sharing forum, each teacher could listen to the experiences of other teachers, which encouraged exchanges and inspired the design of teaching.

Figure 2. Training workshops and meetings for teachers to develop their STEM activities

After the teachers had implemented STEM activities, they were encouraged to complete the questionnaire. Finally, a total of 307 questionnaires were returned. These teachers were from 25 high schools and senior high schools in Taiwan. The distribution of the teachers in northern, central, southern, and eastern Taiwan was 42%, 42%, 9%, and 6%, respectively. The percentages of male and female teachers were 42% and 58% respectively.

4.2. Instruments

To achieve the purpose of this study, the questionnaires of teachers' preferences for and perceptions of STEM activities were adopted to measure the teachers' perceptions of conducting STEM activities. All items in the questionnaire were on a 5-point Likert scale ranging from "1 - *Strongly Disagree*" to "5 - *Strongly Agree*."

The teachers' preference for the STEM activities questionnaire consisted of four dimensions, that is, activity flexibility, technology support, classroom interaction, and teaching assistance, with four, five, five, and five items, respectively. The activity flexibility factor was developed by Paechter and Maier (2010), and measures the extent to which teachers prefer that STEM activities provide more learner control. For example, "I prefer STEM activities that provide learners with opportunities for self-directed learning." The technology factor was developed by Sun et al. (2008), and measures teachers' preference for technology in STEM. For example, "I prefer the quality of wireless internet provided by the school to help me with my teaching activities." The classroom interaction and teaching assistance factor were revised from Arbaugh (2002). Classroom interaction was used to measure the teachers' preference that STEM activities provide more peer and teacher interaction. For example, "I prefer the STEM learning environments that effectively support me in guiding students through discussions." Lastly, the teaching assistance measured the teachers' preference for a STEM teaching community. For example, "I prefer that my school's STEM teaching community can help me fix my own teaching activity weaknesses."

The perception of STEM activities consisted of three dimensions, that is, higher order thinking (10 items), collaboration (7 items), and attitude toward STEM activities (6 items). The factor of higher order thinking was revised from the measures developed by Chai et al. (2015) and Schraw and Dennison (1994). It was used to measure teachers' expectations of STEM learning to enhance students' critical thinking or metacognitive skills. For example, "I expect that when students engage in STEM learning they can ask themselves questions to test their level of proficiency." On the other hand, the factor of collaboration was revised from the measures developed by Lin and Tsai (2013) and Lee et al. (2014). It was used to measure teachers' expectations that STEM teaching would enhance students' teamwork and communication. For instance, "I expect students to be proactive in discussing STEM learning with their classmates and come up with new ideas." Lastly, the attitude toward STEM activities was revised from the measure developed by Lee and Tsai (2010). It measured the extent of teachers' attitude toward conducting STEM activities, for example, "STEM learning can enhance students' learning motivation."

4.3. Data analysis

This study involved two phases of the data analysis procedure, that is confirmatory factor analysis (CFA), and structural equation modeling (SEM).

The finalization of the questionnaires was conducted through confirmatory factor analysis (CFA), which clarified the structure of each dimension and examined the construct validity of the questionnaires. The CFA employed the IBM SPSS Amos software to confirm the validity of the scales in the questionnaires (Jöreskog & Sörbom, 1993).

Second, the structure relationships existing between the three dimensions were explored through a structural equation modeling (SEM) analysis. All analyses of SEM in this study were based on a significance level of $p = 0.05$. First, the descriptive statistics were performed to verify the skewness and kurtosis of the values and to establish the data's univariate normality. The critical values were ±3 and ±8, respectively (Kline, 2010). Also, we measured the multivariate normality using Mardia's normalized multivariate kurtosis (Mardia, 1970).

5. Result

5.1. Test of the measurement model

First, CFA was conducted to verify the construct validity of the three questionnaires in this study. The construct (scale) and measurement (item), the descriptive data (mean and SD), the item factor loadings, *t* value, average variance extracted (AVE), composite reliability (CR), and alpha value are shown in the tables to evaluate the convergent validity of the two questionnaires' constructs.

In Table 1, the result shows that each scale in Preparation of STEM activity consists of four to five items. All the values of factor loadings are significant ($p < .05$) and higher than 0.5. The AVE values range from 0.45 to 0.68; the CR values are all higher than 0.7 and range from 0.77 to 0.91; and the alpha values range from .75 to .91 with an overall alpha of .95. The convergent validity of the construct is adequate (Fornell & Larcker, 1981). With respect to the goodness-of-fit of the construct measurement, the ratio of the Chi-square to degree of freedom = 2.18, GFI = 0.90, AGFI = 0.87, CFI = 0.96, RMSEA = 0.06, and SRMR = 0.04, showing a good model fit for this construct.

Table 1. The confirmatory factor analysis for the preference of STEM activity questionnaire

Construct and measurement items	Mean	*SD*	Factor loading	*t*-value	AVE	CR	Alpha value
Activity flexibility	4.38	0.46			0.45	0.77	0.75
AF1			0.51	8.69***			
AF2			0.70	12.72***			
AF3			0.72	13.25***			
AF4			0.74	13.83***			
Technology support	4.25	0.62			0.67	0.91	0.91
TS1			0.76	15.33***			
TS2			0.88	16.49***			
TS3			0.88	19.00***			
TS4			0.81	16.73***			
TS5			0.85	18.12***			
Classroom interaction	4.28	0.54			0.67	0.91	0.91
CI1			0.86	18.34***			
CI2			0.84	17.89***			
CI3			0.78	15.95***			
CI4			0.79	16.31***			
CI5			0.82	17.19***			
Teaching assistance	4.39	0.55			0.68	0.91	0.91
TA1			0.78	16.02***			
TA2			0.79	16.30***			
TA3			0.81	16.83***			
TA4			0.85	18.15***			
TA5			0.87	18.84***			

Note. Overall alpha, 0.95; AVE, average variance extracted; CR, composite reliability. $^{***}p < .001$.

Similarly, CFAs were conducted to verify the construct validity of the perception of STEM activities. In Table 2, the result shows that each construct consisted of 10 and seven items. All of the factor loading values are significant ($p < .05$) and higher than 0.7. The AVE values are all higher than 0.6 and range from 0.62 to 0.70, the CR values are all higher than 0.9 and range from 0.92 to 0.96, and the alpha values range from .92 to .96 with an overall alpha of .97. With respect to the goodness-of-fit of the constructs, the ratio of the Chi-square to degree of freedom = 2.71, GFI = 0.88, AGFI = 0.85, CFI = 0.96, RMSEA = 0.08, and SRMR = 0.03, showing a good model fit.

CFA was also conducted to verify the construct validity of the attitude toward STEM activities with only one construct (six items). In Table 3, the results show that all the factor loading values are significant ($p < .05$) and higher than 0.5. The AVE value is 0.70 which is higher than 0.5, the CR value is 0.93 which is higher than 0.7, and the alpha value is also .93. With respect to the goodness-of-fit of the constructs, the ratio of the Chi-square to degree of freedom = 3.07, GFI = 0.98, AGFI = 0.94, CFI = 0.99, RMSEA = 0.08, and SRMR = 0.02, showing a good model fit.

In addition, the overall CFA shows that all the factor loadings of the measured items are higher than the threshold value of 0.51. The range of composite reliability (CR) is 0.76~0.96, and the range of average variance extracted (AVE) is 0.45~0.72, indicating that the present study has good convergence validity of the adopted variables. In addition, the study further compared the correlation coefficient of each variable with its square root of AVE. If the square root of AVE is larger than its correlation coefficient, this shows that each construct has close correlation with the theory itself rather than other theories. In the current study, most of the square roots of AVE are larger than their correlation coefficient. As a result, each variable adopted in the present study has its discriminant validity (Yang et al., 2000).

Table 2. The confirmatory factor analysis for the perception of STEM questionnaire

Construct and measurement items	Mean	*SD*	Factor loading	*t*-value	AVE	CR	Alpha value
Higher order thinking	4.00	0.66			0.70	0.96	0.96
HT1			0.84	17.90^{***}			
HT2			0.82	17.54^{***}			
HT3			0.84	18.11^{***}			
HT4			0.84	18.06^{***}			
HT5			0.84	18.16^{***}			
HT6			0.85	18.47^{***}			
HT7			0.81	17.05^{***}			
HT8			0.82	17.46^{***}			
HT9			0.84	17.93^{***}			
HT10			0.86	18.67^{***}			
Collaboration	4.19	0.59			0.62	0.92	0.92
CL1			0.75	15.20^{***}			
CL2			0.68	13.35^{***}			
CL3			0.77	15.65^{***}			
CL4			0.89	19.64^{***}			
CL5			0.88	19.17^{***}			
CL6			0.74	14.91^{***}			
CL7			0.78	15.98^{***}			

Note. Overall alpha, .97; AVE, average variance extracted; CR, composite reliability. $^{***}p < .001$.

Table 3. The confirmatory factor analysis for the satisfaction of STEM

Construct and measurement items	Mean	*SD*	Factor loading	*t*-value	AVE	CR	Alpha value
Attitude toward of STEM activities	4.37	0.59			0.72	0.93	0.93
AT1			0.86	18.37^{***}			
AT2			0.88	19.29^{***}			
AT3			0.81	16.91^{***}			
AT4			0.86	18.45^{***}			
AT5			0.83	17.51^{***}			

Note. AVE, average variance extracted; CR, composite reliability. $^{***}p < .001$.

5.2. Test of the structural model

Path analysis was utilized to measure the structural model in the second stage of SEM analysis. With respect to the goodness-of-fit of the model, the ratio of the Chi-square to degree of freedom = 1.76, GFI = 0.83, AGFI = 0.80, CFI = 0.95, RMSEA = 0.05, and SRMR = 0.04. The GFI and AGFI values of this sample, 0.83 and 0.80, are below 0.9, but could be deemed as a moderate fit (Doll et al., 1994). The CFI value is close to 0.9, which shows a relatively acceptable fit (Norberg et al., 2007).

The structural relationships among Preference and perception of STEM activities are revealed in Figure 3. The conception of Preference of STEM activities as "Technology Support" and "Classroom Interaction" are significant and positive factors explaining "Higher order thinking" in Perception of STEM activities ($\gamma = 0.22$ and 0.60, $p < .01$ and .001). The two factors are also significant and positive factors explaining "Collaboration" in Perception of STEM activities ($\gamma = 0.15$ and 0.71, $p < .05$ and .001). The conception of Preference of STEM activity as "Activity flexibility" and "Teaching assistance" is significant and positive in explaining "Attitude toward STEM activities" in Perception of STEM activities ($\gamma = 0.22$ and 0.23, $p < .01$ and .001). In addition, "Collaboration" in Perception of STEM activities is a significant and positive factor which relates to "Attitude toward STEM activities" ($\gamma = 0.49$, $p < .001$).

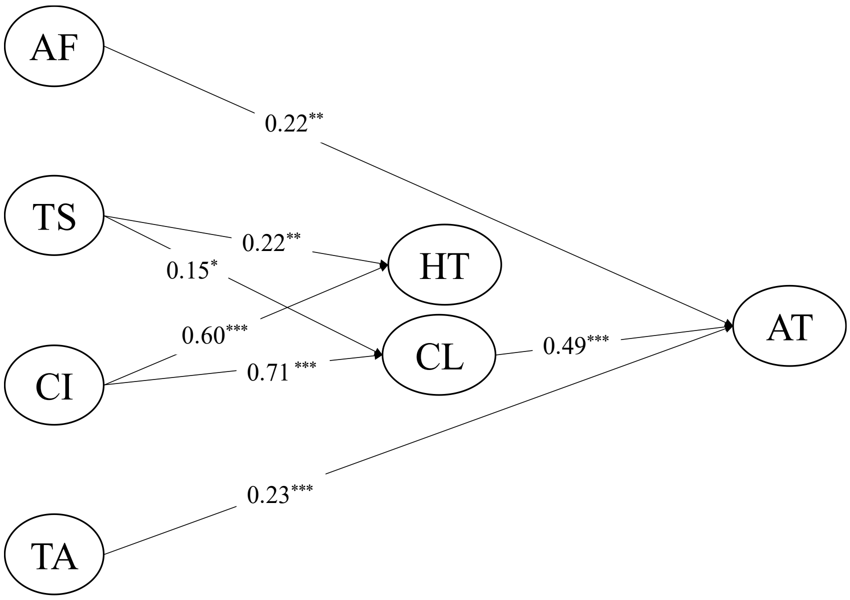

Figure 3. Structural model of the relationships to the teachers' preferences for and perceptions of STEM activities. *Note.* AF = Activity flexibility; TS = Technology support; CI = Classroom interaction; TA = Teaching assistance; HT = Higher order thinking; CL = Collaboration; AT = Attitude toward STEM activities.

In summary, teachers' Preference for STEM activities links to their perceptions of STEM activities. Only two scales of Preference for STEM activity, "activity flexibility" and "teaching assistance," directly link to their attitude toward STEM activities. However, by testing the mediation effect through bootstrapping, teachers' preferences for SEM activities as "Technology support" and "Classroom interaction" play indirect-only mediating roles in their attitude toward STEM activities (standard regression weight = 0.15, $p < .05$, and 0.71, $p < .001$) through their "collaboration" perception of STEM activities.

Table 4 shows the standardized total effect, direct and indirect effects of each variable in the model. The range of the standardized total effect of the predicted variables on the dependent variables in this research model is 0.07-0.60. According to the research model, three endogenous constructs were tested: TS and CI jointly explained HT and CL; the explanatory power was 60% and 68%, respectively, which belonged to the medium to large explanatory power. On the other hand, AF, TS, CI and TA together explained 70% of the variation in AT, which belonged to the medium to large explanatory power. According to the result, it was found that the teachers believed that CI and CL play an important role in STEM activities.

Table 4. Tests of direct and indirect effects

Endogenous variable	Determinant	Direct effect	Indirect effect	Total effect
HT ($R^2 = 0.60$)	TS	0.22		0.22
	CI	0.60		0.60
CL ($R^2 = 0.68$)	TS	0.15		0.15
	CI	0.71		0.71
AT ($R^2 = 0.70$)	AF	0.23		0.23
	TS	-	0.07	0.07
	CI	-	0.35	0.35
	TA	0.22		0.22
	CL	0.49		0.49

Note. AF = Activity flexibility; TS = Technology support; CI = Classroom interaction; TA = Teaching assistance; HT = Higher order thinking; CL = Collaboration; AT = Attitude toward STEM activities.

6. Discussion and conclusion

In this study, the teachers' preferences for and perceptions of STEM activities were investigated. According to the structural equation model, the positive predictive link from "Technology support" and "Classroom interaction" indicated the importance of providing hardware support for teachers. For example, students have access to a smooth wireless network and easy-to-use mobile devices for learning activities. The classroom environment was ideal for group work and discussion. The provision of two environmental and equipment factors was correlated with teachers' perceptions of STEM activities. In fact, this also reflected the teachers' perception of teaching infrastructure and hardware. They considered that while professional training for activity development was important, there should also be an effective mix of teaching hardware and environment.

A positive predictor was also found from "collaboration" to the teachers' attitude toward STEM activities. In other words, the teachers' perception of collaboration is an important mediator between their preferences for STEM activities and attitude toward STEM activities. This study not only reflected the importance of collaboration in teaching and learning, which has been emphasized in many studies in the past (Brand, 2020; Lin et al., 2020), but also illustrated the importance of team problem solving and teacher-student interaction in STEM education. Therefore, when designing STEM activities in the future, it is important to consider not only how well the curriculum is structured for learning, but also whether the students' roles in the activities are clearly defined.

On the other hand, "activity flexibility" and "teaching assistance" performed positive correlation with "attitude toward STEM activities." This result suggested that soft support (e.g., curriculum training and teacher community functioning) can enhance teachers' belief in STEM teaching. Although these two types of support were not directly related to teachers' perceptions of higher order thinking and collaboration, they did have some degree of effectiveness in terms of increasing teachers' beliefs about STEM teaching and learning.

Based on the above findings, the following recommendations are made for future education practitioners:

- School managers should provide support to teachers according to their needs during the curriculum development and teaching process (Adov et al., 2020). For example, teachers should be encouraged to form a community of teachers to develop STEM activities that are unique and sustainable to enhance their attitude in teaching. Friendly collaborative learning spaces and teacher-student interaction can enhance teachers' satisfaction in their teaching.
- It is important to provide a good hardware environment. Including the aforementioned wireless networks and collaborative learning spaces, and encouraging teachers to design activities that make use of collaborative learning strategies can also enhance teachers' perception of STEM education.
- School administrators can organize in-school discussion sessions or cross-school experience sharing sessions. Facilitators can use issue-based discussions and arrange for teachers to co-design teaching plans, for example, discussing the design of cross-curricular activities for the health and science curriculum under COVID-19. By discussing common issues in their lives, teachers can contribute their expertise and creativity to each other.

However, there are still some limitations to this study that should be noted, such as the lack of discussion of students' STEM learning preferences, making it difficult to compare differences in the teachers' and students' preferences. Also, this study only discussed the teachers' self-presentation scales but not their actual teaching effectiveness. Therefore, this study also provides research recommendations for future interested researchers, as follows.

- Researchers can consider comparing the preferences of teachers and students for STEM education, and examine the needs of both samples for teaching and learning through qualitative research.
- Relevant research can also take teachers' teaching plans and actual teaching effectiveness into account to understand teachers' demands for STEM from multiple perspectives.
- It is suggested that students' learning achievement as well as their higher order thinking performance in the context of technology-assisted classroom interaction be evaluated.

Acknowledgement

This study is supported in part by the Ministry of Science and Technology of Taiwan under contract number 109-2511-H-152 -004 -MY2.

References

Adov, L., Pedaste, M., Leijen, A., & Rannikmae, M. (2020). Does it have to be easy, useful, or do we need something else? STEM teachers' attitudes towards mobile device use in teaching. *Technology Pedagogy and Education, 29*(4), 511-526.

Altmeyer, K., Kapp, S., Thees, M., Malone, S., Kuhn, J., & Brünken, R. (2020). The Use of augmented reality to foster conceptual knowledge acquisition in STEM laboratory courses-Theoretical background and empirical results. *British Journal of Educational Technology, 51*(3), 611-628.

Affouneh, S., Salha, S., Burgos, D., Khlaif, Z. N., Saifi, A. G., Mater, N., & Odeh, A. (2020). Factors that foster and deter STEM professional development among teachers. *Science Education, 104*(5), 857-872.

Angel-Alvarado, R., Belletich, O., & Wilhelmi, M. R. (2020). Exploring motivation in music teachers: The Case of three primary schools in Spain. *British Journal of Music Education, 37*(3), 196-206.

Arbaugh, J. B. (2002). Managing the on-line classroom: A Study of technological and behavioral characteristics of web-based MBA courses. *The Journal of High Technology Management Research, 13*(2), 203-223.

Beege, M., Ninaus, M., Schneider, S., Nebel, S., Schlemmel, J., Weidenmuller, J., Moeller, K., & Rey, G. D. (2020). Investigating the effects of beat and deictic gestures of a lecturer in educational videos. *Computers & Education, 156*, Article 103955. doi:10.1016/j.compedu.2020.103955

Bloom, B. S., Engelhart, M. D., Furst, E. J., Hill, W. H., & Krathwohl, D. R. (1956). *Taxonomy of educational objectives Handbook I Cognitive domain*. New York, NY: David McKay.

Brand, B. R. (2020). Integrating science and engineering practices: outcomes from a collaborative professional development. *International Journal of Stem Education, 7*(1), Article 13. doi:10.1186/s40594-020-00210-x

Cedefop (2017). *Defining, writing and applying learning outcomes: A European handbook*. Luxembourg: European Centre for the Development of Vocational Training.

Century, J., Ferris, K. A., & Zuo, H. F. (2020). Finding time for computer science in the elementary school day: A Quasi-experimental study of a transdisciplinary problem-based learning approach. *International Journal of STEM Education, 7*(1), Article 20.

Chai, C. S., Deng, F., Tsai, P. S., Koh, J. H. L., & Tsai, C. C. (2015). Assessing multidimensional students' perceptions of twenty-first-century learning practices. *Asia Pacific Education Review, 16*, 389–398 (2015). doi:10.1007/s12564-015-9379-4

Chang, C. C., & Chen, Y. (2020). Using mastery learning theory to develop task-centered hands-on STEM learning of Arduino-based educational robotics: psychomotor performance and perception by a convergent parallel mixed method. *Interactive Learning Environments*, 1-16. doi:10.1080/10494820.2020.1741400

Chuang, S. C., & Tsai, C. C. (2005). Preferences toward the constructivist Internet-based learning environments among high school students in Taiwan. *Computers in Human Behavior, 21*(2), 255-272. doi:10.1016/j.chb.2004.02.015

Dong, Y., Wang, J., Yang, Y. Y., & Kurup, P. M. (2020). Understanding intrinsic challenges to STEM instructional practices for Chinese teachers based on their beliefs and knowledge base. *International Journal of STEM Education, 7*(1), Article 47. doi:10.1186/s40594-020-00245-0

Doll, W. J., Xia, W., & Torkzadeh, G. (1994). A Confirmatory factor analysis of the end-user computing satisfaction instrument. *MIS Quarterly*, *18*(4), 453-461.

El Nagdi, M., Leammukda, F., & Roehrig, G. (2018). Developing identities of STEM teachers at emerging STEM schools. *International Journal of Stem Education, 5*(1), 1-13. doi:10.1186/s40594-018-0136-1

El Nagdi, M., & Roehrig, G. (2020). Identity evolution of STEM teachers in Egyptian STEM schools in a time of transition: A Case study. *International Journal of Stem Education, 7*(1), Article 41. doi:10.1186/s40594-020-00235-2

Ertmer, P. A. (2005). Teacher pedagogical beliefs: The Final frontier in our quest for technology integration? *Etr&D-Educational Technology Research and Development, 53*(4), 25-39. doi:10.1007/bf02504683

Fornell, C., & Larcker, D. F. (1981). Evaluating structural equation models with unobservable variables and measurement error. *Journal of Marketing Research*, *18*(1), 39-50.

Franquesa-Soler, M., Barraza, L., & Serio-Silva, J. C. (2019). Children's learning preferences for the development of conservation education programs in Mexican communities. *Journal of Educational Research, 112*(1), 28-37. doi:10.1080/00220671.2018.1427038

Gale, J., Alemdar, M., Lingle, J., & Newton, S. (2020). Exploring critical components of an integrated STEM curriculum: An Application of the innovation implementation framework. *International Journal of STEM Education, 7*(1), Article 5. doi:10.1186/s40594-020-0204-1

Gardner, M. A., & Tillotson, J. W. (2020). Explorations of an integrated STEM middle school classroom: Understanding spatial and temporal possibilities for collective teaching. *International Journal of Science Education, 42*(11), 1895-1914. doi:10.1080/09500693.2020.1794078

Garet, M. S., Porter, A. C., Desimone, L., Birman, B. F., & Yoon, K. S. (2001). What makes professional development effective? Results from a national sample of teachers. *American Educational Research Journal, 38*(4), 915-945. doi:10.3102/00028312038004915

Gosling, D., & Moon, J. (2002). *How to use learning outcomes and assessment criteria*. London, UK: SEEC.

Holmlund, T. D., Lesseig, K., & Slavit, D. (2018). Making sense of "STEM education" in K-12 contexts. *International Journal of Stem Education, 5*(1), 1-18. doi:10.1186/s40594-018-0127-2

Hu, C. C., Yeh, H. C., & Chen, N. S. (2020). Enhancing STEM competence by making electronic musical pencil for non-engineering students. *Computers & Education, 150*, 103840. doi:10.1016/j.compedu.2020.103840

Hwang, G. J., Chu, H. C., & Lai, C. L. (2017). Prepare your own device and determination (PYOD): A Successfully promoted mobile learning mode in Taiwan. *International Journal of Mobile Learning and Organisation, 11*(2), 87-107.

Hwang, G. J., Li, K. C., & Lai, C. L. (2020). Trends and strategies for conducting effective STEM research and applications: A Mobile and ubiquitous learning perspective. *International Journal of Mobile Learning and Organisation*, *14*(2), 161-183.

Hwang, G. J., Lai, C. L., Liang, J. C., Chu, H. C., & Tsai, C. C. (2018). A Long-term experiment to investigate the relationships between high school students' perceptions of mobile learning and peer interaction and higher-order thinking tendencies. *Etr&D-Educational Technology Research and Development, 66*(1), 75-93. doi:10.1007/s11423-017-9540-3

Jöreskog, K. G., & Sörbom, D. (1993). *LISREL 8: Structural Equation Modeling with the SIMPLIS Command Language*. Scientific Software International. Retrieved from http://books.google.com.tw/books?id=f61i3quHcv4C

Kelley, T. R., Knowles, J. G., Holland, J. D., & Han, J. (2020). Increasing high school teachers self-efficacy for integrated STEM instruction through a collaborative community of practice. *International Journal of STEM Education, 7*(1), 1-13. doi:10.1186/s40594-020-00211-w

Kline, R. B. (2005). *Principles and practice of structural equation modeling* (2nd ed.). New York, NY: Guilford Press.

Kong, S. C., Chan, T. W., Griffin, P., Hoppe, U., Huang, R. H., Kinshuk, Looi, C. K., Milrad, M., Norris, C., Nussbaum, M., Sharples, M., So, W., Soloway, E., & Yu, S. Q. (2014). E-learning in school education in the coming 10 years for developing 21st century skills: Critical research issues and policy implications. *Educational Technology & Society, 17*(1), 70-78.

Kong, S. C., Lai, M., & Sun, D. E. (2020). Teacher development in computational thinking: Design and learning outcomes of programming concepts, practices and pedagogy. *Computers & Education, 151*, 103872. doi:10.1016/j.compedu.2020.103872

Lee, K., Tsai, P. S., Chai, C. S., & Koh, J. H. L. (2014). Students' perceptions of self-directed learning and collaborative learning with and without technology. *Journal of Computer Assisted Learning, 30*(5), 425-437.

Lee, M. H., & Tsai, C. C. (2010). Exploring teachers' perceived self efficacy and technological pedagogical content knowledge with respect to educational use of the World Wide Web. *Instructional Science*, *38*(1), 1-21.

Li, Y. H., Yang, H. H., & MacLeod, J. (2019). Preferences toward the constructivist smart classroom learning environment: Examining pre-service teachers' connectedness. *Interactive Learning Environments, 27*(3), 349-362. doi:10.1080/10494820.2018.1474232

Liang, J. C., & Tsai, C. C. (2008). Internet self-efficacy and preferences toward constructivist Internet-based learning environments: A Study of pre-school teachers in Taiwan. *Educational Technology & Society, 11*(1), 226-237.

Lin, C. L., Liang, J. C., Su, Y. C., & Tsai, C. C. (2013). Exploring the relationships between self-efficacy and preference for teacher authority among computer science majors. *Journal of Educational Computing Research, 49*(2), 189-207. doi:10.2190/EC.49.2.d

Lin, K. Y., Yu, K. C., Hsiao, H. S., Chang, Y. S., & Chien, Y. H. (2020). Effects of web-based versus classroom-based STEM learning environments on the development of collaborative problem-solving skills in junior high school students. *International Journal of Technology and Design Education, 30*(1), 21-34. doi:10.1007/s10798-018-9488-6

Liu, S. H. (2020). Effects of an online sharing and feedback programme on preservice teachers' practical knowledge, learning preferences and satisfaction. *Technology Pedagogy and Education, 29*(4), 463-475. doi:10.1080/1475939x.2020.1788980

Lou, S. J., Tsai, H. Y., Tseng, K. H., & Shih, R. C. (2014). Effects of implementing STEM-I project-based learning activities for female high school students. *International Journal of Distance Education Technologies (IJDET)*, *12*(1), 52-73.

Mardia, K. V. (1970). Measures of multivariate skewness and kurtosis with applications. *Biometrika*, *57*(3), 519-530.

Martín-Páez, T., Aguilera, D., Perales-Palacios, F. J., & Vílchez-González, J. M. (2019). What are we talking about when we talk about STEM education? A Review of literature. *Science Education*, *103*(4), 799-822.

McElearney, A., Murphy, C., & Radcliffe, D. (2019). Identifying teacher needs and preferences in accessing professional learning and support. *Professional Development in Education, 45*(3), 433-455. doi:10.1080/19415257.2018.1557241

Mishra, P., & Koehler, M. J. (2006). Technological pedagogical content knowledge: A Framework for teacher knowledge. *Teachers College Record, 108*(6), 1017-1054. doi:10.1111/j.1467-9620.2006.00684.x

Mustafa, N., Ismail, Z., Tasir, Z., & Mohamad Said, M. N. H. (2016). A Meta-analysis on effective strategies for integrated STEM education. *Advanced Science Letters*, *22*(12), 4225-4228.

Ng, O. L., & Chan, T. (2021). In-service mathematics teachers' video-based noticing of 3D printing pens "in action". *British Journal of Educational Technology*, *52*(2), 751-767. doi:10.1111/bjet.13053

Norberg, M., Stenlund, H., Lindahl, B., Andersson, C., Weinehall, L., Hallmans, G., & Eriksson, J. W. (2007). Components of metabolic syndrome predicting diabetes: No Role of inflammation or dyslipidemia. *Obesity*, *15*(7), 1875-1885.

Ogbuanya, T. C., & Efuwape, B. M. (2018). Technology-aided learning environment: An Investigation into electrical/electronics students' instructional preferences, attitude and approaches to learning. *South African Journal of Education, 38*, Article 1535. doi:10.15700/saje.v38ns2a1535

Okumus, S., Lewis, L., Wiebe, E., & Hollebrands, K. (2016). Utility and usability as factors influencing teacher decisions about software integration. *Etr&D-Educational Technology Research and Development, 64*(6), 1227-1249. doi:10.1007/s11423-016-9455-4

Paechter, M., & Maier, B. (2010). Online or face-to-face? Students' experiences and preferences in e-learning. *The Internet and Higher Education, 13*(4), 292-297.

Patten, B., Arnedillo Sánchez, I., & Tangney, B. (2006). Designing collaborative, constructionist and contextual applications for handheld devices. *Computers & Education, 46*(3), 294-308. doi:10.1016/j.compedu.2005.11.011

Sandholtz, J. H., & Ringstaff, C. (2020). Offering modest supports to extend professional development outcomes and enhance elementary science teaching. *Professional Development in Education*. doi:10.1080/19415257.2020.1725594

Schraw, G., & Dennison, R.S. (1994). Assessing metacognitive awareness. *Contemporary Educational Psychology, 19*(4), 460-475.

Shernoff, D. J., Sinha, S., Bressler, D. M., & Ginsburg, L. (2017). Assessing teacher education and professional development needs for the implementation of integrated approaches to STEM education. *International Journal of Stem Education, 4*(1), 1-16. doi:10.1186/s40594-017-0068-1

Siew, N. M., Amir, N., & Chong, C. L. (2015). The Perceptions of pre-service and in-service teachers regarding a project-based STEM approach to teaching science. *SpringerPlus*, *4*(1), 1-20. doi:10.1186/2193-1801-4-8

Simeon, M. I., Samsudin, M. A., & Yakob, N. (2020). Effect of design thinking approach on students' achievement in some selected physics concepts in the context of STEM learning. *International Journal of Technology and Design Education*. doi:10.1007/s10798-020-09601-1

Song, Y. J., & Hwang, G. J. (2020). What "seams" have been bridged in seamless vocabulary learning? A Review of the literature. *Interactive Learning Environments*. doi:10.1080/10494820.2020.1789667

Stehle, S. M., & Peters-Burton, E. E. (2019). Developing student 21st century skills in selected exemplary inclusive STEM high schools. *International Journal of Stem Education, 6*(1), 1-15. doi:10.1186/s40594-019-0192-1

Sun, P.-C., Tsai, R. J., Finger, G., Chen, Y.-Y., & Yeh, D. (2008). What drives a successful e-learning? An Empirical investigation of the critical factors influencing learner satisfaction. *Computers & Education, 50*(4), 1183-1202.

Wahono, B., & Chang, C. Y. (2019). Assessing teacher's attitude, knowledge, and application (AKA) on STEM: An Effort to foster the sustainable development of STEM education. *Sustainability*, *11*(4), 950. doi:10.3390/su11040950

Wahono, B., Lin, P. L., & Chang, C. Y. (2020). Evidence of STEM enactment effectiveness in Asian student learning outcomes. *International Journal of Stem Education, 7*(1), 1-18. doi:10.1186/s40594-020-00236-1

Wang, H. H., Charoenmuang, M., Knobloch, N. A., & Tormoehlen, R. L. (2020). Defining interdisciplinary collaboration based on high school teachers' beliefs and practices of STEM integration using a complex designed system. *International Journal of Stem Education, 7*(1), 1-17. doi:10.1186/s40594-019-0201-4

Wei, B. (2020). An Exploratory study of teacher development in the implementation of integrated science curriculum. *Research in Science Education, 50*(6), 2189-2206. doi:10.1007/s11165-018-9768-x

Wu, T., & Albion, P. (2019). Investigating remote access laboratories for increasing pre-service teachers' STEM capabilities. *Educational Technology & Society, 22*(1), 82-93.

Yang, N., Chen, C. C., Choi, J., & Zou, Y. (2000). Sources of work-family conflict: A Sino-US comparison of the effects of work and family demands. *Academy of Management Journal, 43*(1), 113-123.

Yeh, H. C., & Tseng, S. S. (2019). Using the ADDIE model to nurture the development of teachers' CALL professional knowledge. *Educational Technology & Society, 22*(3), 88-100.

Yu, K. C., Wu, P. H., & Fan, S. C. (2020). Structural relationships among high school students' scientific knowledge, critical thinking, engineering design process, and design product. *International Journal of Science and Mathematics Education, 18*(6), 1001-1022. doi:10.1007/s10763-019-10007-2