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Research Article

A Conceptual Model of Teaching Efficacy and Beliefs, Teaching Outcome Expectancy, Student Technology Use, Student Engagement, and 21st-Century Learning Attitudes: A STEM Education Study

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ABSTRACT

The need to train and equip students in science and mathematics integrated with technology, according to contemporary professions, has gained a lot of attention. Careers in this field demand that students do not just explore single subjects working independently, but rather look at how they can be integrated for application in real-world problems, provide solutions and help us take such an approach in STEM education. The use of technology enhances students' learning and acts as an effective strategy for engaging a student in a science and mathematics classroom session. For implementing a meaningful STEM class, the teachers' efficacy and beliefs, their perceptions of effective technological use by students to improve learning, their teaching outcome and expectancy, student engagement and 21st-century learning attitudes inculcated in students need to be looked into. The present study is a correlational one investigating the effect of teaching efficacy and beliefs, teaching outcome expectancy and 21st-century learning on student engagement. The results of the study show that students' use of technology has a mediating effect on the relationship between teaching efficacy and beliefs and student engagement, whereas 21st-century learning attitudes do not have any mediating effect. Both student technology uses and 21st-century learning attitudes have a mediating effect on the relationship between teaching outcome expectancy and student engagement.

Keywords: STEM education, teaching efficacy and beliefs, student technology use, student engagement, 21st-century skills

INTRODUCTION

Science, technology, engineering, and mathematics (STEM) education has gained a lot of attention, as the problems that we face globally are multidisciplinary and call for an integrated approach in management (Wang et al., 2011). The National Science Foundation (NSF) has contributed largely to STEM education by promoting research in these four disciplines in the USA. This has led to an increased number of STEM-related studies and the number of schools which focused on STEM in the USA (Holmlund et al., 2018). A major goal of STEM education is to focus on increasing student interest and proficiency in STEM irrespective of their future careers, as it imparts 21st-century skills such as critical thinking, problem-solving, teamwork, and collaboration, to name a few (Howard-Brown & Martinez, 2012; Orpwood et al., 2012). NSF's review (2012, as cited in Darling-Hammond et al., 2019) suggests that these kinds of higher-order thinking skills can be developed in classrooms that are focused on inquiry and investigation-based learning, applying knowledge, and skills to real-world scenarios and working collaboratively with each other through hands-on experience. Darling-Hammond et al. (2019) suggest the following instructional strategies that could be used as part of STEM education: Work that is meaningful and focused on building prior knowledge of students, which demands them to be actively engaged, in the task and thus build conceptual knowledge and skills; focus on inquiry-based learning with opportunities to practice and apply the learning in various situations; opportunities for collaborative learning that encourage students to question and explain their ideas and construct solutions and finally regular assessments that enable students to improve on their work and take the opportunities to reflect on their learning. For the purpose of imparting an in-depth experience of STEM education, it is necessary that teachers must be well-skilled and have unique, pedagogical skills with not just knowledge of their discipline, but awareness of the content of other disciplines as well (Margot & Kettler, 2019). Teachers felt the importance of integrating STEM into the daily K-12 classrooms and took a positive outlook toward integrating them into classrooms (Koc Akran & Asiroglu, 2018; Margot & Kettler, 2019; Park et al., 2016).

In India, the government's efforts to implement STEM is evident through Rashtriya Madhyamik Shiksha Abhiyan (RMSA), which has been redesigned as 'Vocationalization of Higher Secondary Education'. Around 15,000 students from 3,000 schools across 16 states have been trained under this scheme (RMSA, 2017). Each unit design fosters cooperative studying and essential thinking. Teachers facilitate teamwork, as learners actively discuss their findings, file and record data, and examine their understanding. STEM Champ has the power and ability to convert even hostile faculties of schools into locations of inspiration as a network, wherein students are intrinsically motivated, can broaden collaborative behavior, and become successful academically (Malti, 2017).

The Indian government is working towards inculcating scientific temperament in school students through various training programs to upskill them (Sharma & Yarlagadda, 2018). Being the second most populated country, but with unequal skills and cultures, India needs mixed assistance from the authorities and different training societies to avail of the possibilities and advantages of STEM education (Pagar, 2018). To bring out students' inherent abilities, there must be a clear shift toward integrating knowledge and skills in the appropriate proportion for specific jobs. Given the diversity of our country, STEM education should focus on resolving local and regional issues. The importance of meaningfully developing STEM teachers and academic leaders is also emphasized (VIF, 2019). STEM education helps to improve national assessment criteria carried out by the center PARAKH, as per NEP 2020 guidelines. Several groups such as educators and innovators are investing in STEM education to develop talent within the country for the make in India dream project (Raupp, 2020). STEM brings out the best in overall performance to assess and allow us to check and review learning, analyze our knowledge and allow us to enable the holistic improvement of children (Verma, 2021).

Since the pandemic in 2019, education has shifted to the online mode and technology has played a huge role in these challenging times all over the world. Lee and Campbell (2020) explore the use of computational sciences to engage K-12 students in finding solutions to societal problems and explain how traditional teacher roles have been replaced in the present times. Engaging students in virtual labs and experiments that can be conducted at home has gained attention due to the online mode of instruction. Teachers feel the need to get themselves trained professionally to meet their needs, due to the shift in the mode (Larson & Farnsworth, 2020). Massive open online courses (MOOCs) have also helped in the learning process of STEM discipline, to help us gain technological skills and increase teachers' competence (Yildirim, 2020). Therefore, the shift to online education has increased the dependence on technological tools that support STEM education.

The purpose of this research is to assess teacher efficacy, beliefs, and outcomes of teachers in STEM education in the city of Bengaluru. The levels of technology use and student engagement in STEM is also an area that needs to be addressed.

LITERATURE REVIEW

There is a want of skilled laborers in STEM education in this technologically evolving and rapidly changing world. Although STEM education is not well-described, it has a certain structure in its implementation and the goals of STEM education include STEM literacy, 21st-century competencies, STEM workforce readiness, the ability to make connections among STEM disciplines, interests, and engagement (Schweingruber et al., 2014). Moore et al. (2014) has done many reviews on literature followed by an analysis of content materials and has also got in touch with STEM experts to understand the ways in which STEM is being implemented in classrooms.

STEM Integration

STEM integration is not limited to just one kind of approach (English, 2016; Herschbach, 2011). Davison et al. (1995) explain how integrating science and mathematics curriculum will lead to a reality-based learning experience based on five different models of integration. Although it does not deal with technology and engineering, this can be extended to those fields with a similar approach. Breiner et al. (2012) define STEM integration as a shift from the traditional classroom lecture to one that involves a more problem-based approach. Although this method of integration of disciplines has been positively viewed by teachers (Koc Akran & Asiroglu, 2018; Margot & Kettler, 2019; Park et al., 2016), the implementation remains a major challenge (Aldahmash et al., 2019; Herschbach, 2011; Hourigan et al., 2021; Koc Akran & Asiroglu, 2018; Ring et al., 2017). The major difficulties cited are lack of content knowledge and confidence, time constraints, and lack of training. After the completion of professional development in STEM, the above-cited research indicated a positive change in the attitude of teachers to execute STEM education. Nadelson and Seifert (2017) point out the challenges of restructuring the current educational system and curriculum to accommodate STEM structure, as the current educational structure is discipline-based and not problem-based. The second challenge they point out is teachers' STEM knowledge and their professional mindsets. Teachers' perception of their lack of knowledge or unwillingness to learn concepts and content will not support a STEM-integrated approach to teaching and learning. Implementing integrated STEM education requires an educational innovation that takes into account ill-structured problems and pedagogical approaches, which suggest a need for teachers to be risk-takers and lifelong learners (Nadelson et al., 2015).

Teachers' Perceptions in STEM Education

DeCoito and Myszkal (2018) highlight the disparities between teachers' perceptions of implementing STEM and the extent to which it is implemented in reality. Integrative, inquiry-based STEM education is considered to be a feasible way to encourage students in the areas of science and mathematics but teachers' self-efficacy and beliefs about their abilities is a major factor in implementing inquiry-based practices. Sawyer and Myers' (2018) research revealed that preservice teachers at the elementary level used online resources during their lesson planning as compared to the pre-service teachers in the early childhood program. Interviews with the teachers revealed that the early childhood teachers had a lot more field experience thus reducing their dependence on online resources.

Collaboration with peers, excellent curriculum, district support, past experiences, and effective professional development were all examples of assistance that teachers received to help them integrate STEM education. So collaborators documented changes in teachers' STEM conceptions, researchers used a qualitative approach that included pre- and post-concept maps, self-reflections, and interviews with teachers. The findings show that "School-STEM professionals' collaboration" had a positive impact on teachers' perceptions of STEM education and STEM professionals. Five teachers collaborated with an environmental scientist and the research team to design authentic STEM activities to solve a problem affecting the school environment. Teachers struggle to identify assets of quality studies, research work, and how to translate studies to aid their teaching. Teachers' engagement through evidence-based practices has been looked into which has implications for school administrators (Booher et al., 2020). Teachers of higher-grade levels took a positive outlook towards STEM as compared to lower-grade teachers. Professional developments, enough preparation time, and administrative support influenced teachers' attitudes (Hackman et al., 2021). Significant differences were found among teachers in different grades.

Teachers' Self-Efficacy in STEM Education

Teachers' self-efficacy refers to the belief that teachers hold about themselves in executing instructional practices that lead to positive student learning outcomes (Bandura et al., 1999). It is a teacher's self-perceived level of their ability to achieve favorable learning outcomes in a classroom (Lemon & Garvis, 2015). Teachers' self-efficacy has an impact on students' achievements (Caprara et al., 2006; Muijs & Reynolds, 2002), increased job satisfaction (Klassen et al., 2009; Skaalvik & Skaalvik, 2010), and use of a variety of technological tools and innovative teaching methods (Kim et al., 2013). For the purpose of assessing teachers' efficacy in STEM education, the teachers' efficacy and attitudes toward STEM (T-STEM) survey (FIEI, 2012) is used. The T-STEM survey is based on the science teachers' efficacy belief instrument scale (Riggs & Enochs, 1990), which is used to measure outcome expectancies among science teachers. The present study has evidenced the importance of teachers' efficacy by testing the following hypotheses:

Hypothesis 1: There is a mediating role of students' technological use in the relationship between teaching efficacy and beliefs and students' engagement.

Hypothesis 2: There is a mediating role of 21st century learning attitudes in the relationship between teaching efficacy and beliefs and students' engagement.

Students' Engagement in STEM

In STEM education, there is a misunderstanding of what constitutes "engagement." Gender disparities in interests, aspirations, and participation in STEM are causing international concern (Murphy et al., 2019). These calls acknowledge the role that learners' motivation in an emotional response to STEM plays in their participation and achievement in STEM education. Mastery goals are associated with high effort and persistence in STEM, whereas autonomy, relatedness, and growth mindsets improve STEM participation and achievement. Negative emotional responses to STEM can develop early in life and persist throughout schooling.

So et al. (2020) evidenced that students' stereotypical beliefs about STEM careers presume their self-efficacy in STEM activities and their career-related outcome expectations negatively. Furthermore, students' self-efficacy in STEM activities, as well as their expectations for career-related outcomes, predict their STEM career interests (Luo et al., 2021). Middle school-level students have limited STEM career knowledge and the activities that are a part of it. It is also seen that there is a decline in interest in STEM careers for students who have low mathematics self-efficacy (Blotnicky et al., 2018). The present study has evidenced the importance of student engagement by testing the following hypotheses:

Hypothesis 3: There is a mediating role of students' technological use in the relationship between teaching outcome expectancy and students' engagement.

Hypothesis 4: There is a mediating role of 21st-century learning attitudes in the relationship between teaching outcome expectancy and students' engagement.

Professional Development for STEM Education

Gardner et al. (2019) detailed a STEM education framework to implement professional development for one year in non-STEM-focused schools in Southeast USA. The impact of the professional development was assessed which led to the understanding of how the STEM education's descriptive framework could help design appropriate and meaningful professional development for teachers in schools that are not focused on STEM. Bartels et al.'s (2019) study shows the impact of elementary math and science courses when taught collaboratively to teachers in delivering STEM instruction. A one-month-long unit on STEM education concluded with teachers planning and teaching integrated math and science lessons. The teachers' ability to recognize and design STEM lessons improved after the professional development but their beliefs that the lesson needed to cover all the disciplines still remained.

Aldahmash et al.'s (2019) study points to the decreased difficulty that science and mathematics teachers face after professional development. Regular professional developments and workshops on the integration of technology increase teachers' technological skills and help them integrate technology in classrooms (Kim et al., 2013). Geng et al. (2018) report the need for professional development, pedagogical support, and resources for the curriculum to help teachers implement STEM education. The study found a shift in the middle and high-school teachers' attitudes toward interdisciplinary teaching when it came to imparting STEM (al

Salami et al., 2015). Hence, all these studies point to the positive effect that professional developments can have on imparting STEM education.

Need for the Study

An important aspect of integrating STEM in K-12 classes is the approach that teachers take toward STEM and students' engagement in classrooms. Awareness of STEM, effective methods to implement STEM, and increasing student motivation toward STEM-related careers are a few aspects in which teachers play an important role. Studies on teacher awareness and perceptions of STEM education have been conducted in earlier research as seen above and in the review of the literature. STEM education has been found to have a favorable impact on students' learning outcomes in Asia which is seen in their learning achievement, higher-order thinking skills, and motivation (Wahono et al., 2020). For successful implementation of STEM education which impacts students' achievement, teachers' self-efficacy plays a vital role (Caprara et al., 2006; Muijs & Reynolds, 2002). Ottenbreit-Leftwich et al. (2010) point out that when teachers believe technology has an impact on classroom learning, they are more likely to integrate technology and hence promote student learning. 21st-century learning attitudes, such as collaboration and teamwork make classroom science learning enjoyable and interesting, thus increasing students' engagement in class (Duran et al., 2011). Hence teachers' beliefs can impact and promote the use of technology for positive learning outcomes. Students get involved in classroom activities that promote STEM education.

However, not much has been done in studying the effect of teaching efficacy and beliefs, teaching outcome expectancy, student technology use, and 21st-century learning attitudes on student engagement. The present study is hence aimed at exploring these factors that are necessary to implement a STEM classroom successfully. Hence, the triple objectives of the present study are:

1. To explore the mediating effect of students' technological use and 21st-century learning attitudes in the relations between teaching efficacy and beliefs and students' engagement.
2. To explore the mediating effect of students' technological use and 21st-century learning attitudes in the relation between teaching outcome expectancy and students' engagement.
3. To establish a conceptual model of the variables of the study, teaching efficacy and beliefs, teaching outcome expectancy, students' technological use, students' engagement, and 21st-century learning attitudes.

METHODOLOGY

This study is correlational. It examined the mediating roles of students' technological use and 21st-century learning attitudes in two relationships:

1. Between teaching efficacy and beliefs and students' engagement and
2. Between teaching outcome expectancy and students' engagement.

Furthermore, the study tested a conceptual model built on teaching efficacy and beliefs, teaching outcome expectancy, students' technological use, students' engagement, and 21st-century learning attitudes.

Table 1. Sample profile

Variable	Categories	Count	Percent
Gender	Female	59	69.4
	Male	26	30.6
Age	<25 years	17	20.0
	>35 years	30	35.3
	26-35 years	38	44.7
Teaching subject	Mathematics	40	47.1
	Sciences	45	52.9
School level	Primary/middle school	30	35.3
	Secondary/higher secondary school	55	64.7
School board	CBSE	43	50.6
	ICSE	25	29.4
	State	17	20.0
Teaching experience	<5 years	38	44.7
	>11 years	17	20.0
	6-10 years	30	35.3
Professional training in STEM	No	52	61.2
	Yes	33	38.8

Sample and Procedure

The participants of the study consisted of 200 science and mathematics school teachers from Bengaluru, who were selected using the convenience sampling technique (**Table 1**). Data was collected from June 2021 to August 2021 from teachers who fulfilled two inclusion criteria:

1. Teachers of mathematics and sciences (physics, chemistry, biology, and computer science) and
2. Teachers with a minimum of two years of experience.

An ethical permission certificate from the Centre of Research, CHRIST (deemed to be University) was obtained for conducting the research. Consent forms were obtained from the participants, and the data collection process began on a voluntary basis. It took approximately 10 minutes on average to be completed. A total of 85 teachers participated in the survey, which was sent through Google forms via mail. Data was subjected to descriptive and inferential tests using SPSS (v 20) and AMOS (v 22).

Measurement Tools

The data collection tool comprised of seven sections: consent for participation, demographic details, teaching efficacy and beliefs, teaching outcome expectancy, students' technology use, students' engagement, and 21st-century skills. The T-STEM survey (FIEI, 2012) was used to measure the above-mentioned constructs. The T-STEM survey is based on the science teacher efficacy belief instrument scale (Riggs & Enochs, 1990) which is used to measure outcome expectancies among science teachers. The tool consists of 53 items (Likert scale) under five constructs. The teaching efficacy and beliefs, teaching outcome expectancy, and 21st-century skills had responses on the scale varying from 1 (strongly disagree) to 5 (strongly agree). The students' technology uses and students'

Table 2. Means, standard deviation, Cronbach's alpha, and Pearson's coefficient of correlation

	TEB	TOE	STU	SE	CLA
Teaching efficacy and beliefs (TEB)	1				
Teaching outcome expectancy (TOE)	.679**	1			
Student technology use (STU)	.492**	.491**	1		
Student engagement (SE)	.553**	.532**	.835**	1	
21st-century learning attitudes (CLA)	.604**	.468**	.404**	.471**	1
Mean	4.5847	4.1412	3.1662	3.1824	4.7123
Standard deviation	.46432	.64228	.63486	.62363	.38794
Cronbach's alpha	.903	.881	.901	.940	.902

Note. **The significance level of all the values is p<.01

engagement constructs had responses on the scale varying from 1 (never) to 4 (usually).

The teaching efficacy and beliefs construct (10 items) had statements regarding the teachers' feelings about their science and mathematics teaching such as "I am continually improving my teaching practice", "I am confident that I can answer students' questions", and "I know what to do to increase students' interest". The teaching outcome expectancy (nine items) construct had statements with regard to teachers' perceptions about students' learning outcomes in science and mathematics, such as "when a student does better than usual in mathematics, it is often because the teacher exerted a little extra effort", and "students' learning in mathematics is directly related to their teacher's effectiveness". The students' technology use (eight items) construct had statements regarding the extent of use of technology in science and mathematics classes such as "use technology to communicate and collaborate with others, beyond the classroom" and "use technology to help solve problems". The students' engagement construct (14 items) had statements with regard to students' engagement in class as perceived by the teachers such as "develop problem-solving skills through investigations (e.g. scientific, design, or theoretical investigations)" and "create reasonable explanations of results of an experiment or investigation". The 21st-century skills (11 items) construct had statements with regard to the extent of teachers' perception on the importance of skills such as "lead others to accomplish a goal" and "manage their time wisely when working on their own". The reliability analysis of the scales is given in **Table 2**.

RESULTS AND ANALYSIS

In the data analysis, arithmetic means, standard deviation, Pearson's correlation, regression weights, both direct and indirect, and total effects for significance were used. Structural equation modelling analysis was used to compute model fit indices to establish conceptual model fit.

Descriptive Statistics and Correlation

In order to check the assumption of multi-collinearity, a linear regression test was conducted, wherein the variance inflation factor (VIF) values of all independent variables were as follows: Teaching efficacy and beliefs (2.376), teaching outcome expectancy (1.983), student technology use (1.430), and 21st-century learning attitudes (1.619), which interestingly was <10, reflecting thereby the permissible values while indicating that the multi-collinearity assumption was met.

Further, the means and standard deviation were computed for the study variables and detailed in **Table 2**. All the mean values were above average. Pearson's correlation analysis was used to determine the degree and direction of the relationship between teaching efficacy and beliefs, teaching outcome expectancy, student technology use, student engagement, and 21st-century learning attitudes. From **Table 2**, it is evident that there is significant moderate to high correlations between the study variables.

Mediation Analysis

Structural equation modelling (SEM) was used to determine whether the independent variables were a significant predictor of the dependent variable and whether there was a mediating effect of the mediator in the prediction path. Before proceeding with the mediation analysis, the correlation between all variables of the study was reported (**Table 2**). The correlation values have satisfied the assumption that the variables are significantly correlated. Structural equation modelling using maximum likelihood estimates was adopted to test the mediation hypotheses. The most common SEM estimation procedure is maximum likelihood estimation (MLE). MLE is a procedure that iteratively improves parameter estimates to minimize a specified fit function. The MLE selects the set of values of the model's parameters for a fixed set of data and an underlying statistical model that maximizes the likelihood function. To analyze mediation effect, bias correction percentile method was used to calculate the direct, indirect, and total effects.

Figures 1, **Figure 2**, **Figure 3**, and **Figure 4** show the path diagrams of the mediator's role related to hypothesis 1, hypothesis 2, hypothesis 3, and hypothesis 4, respectively.

The results of the direct and indirect effect and the total effect of the mediator on the dependent variable have been

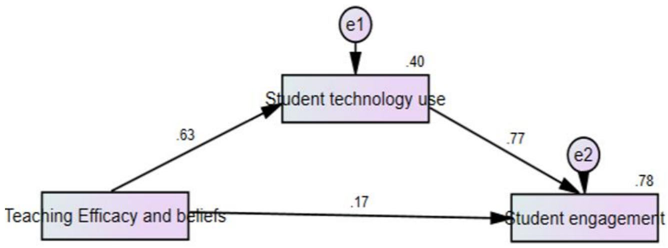

Figure 1. Path diagram of the mediating role of students' technology use in the relationship between teaching efficacy and beliefs and students' engagement (hypothesis 1)

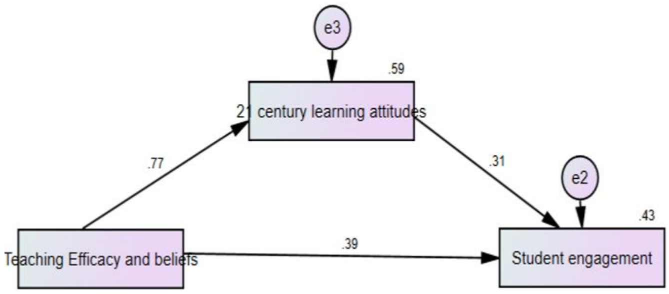

Figure 2. Path diagram of the mediator's role in 21st-century learning attitudes balancing relationship between teaching efficacy and beliefs and students' engagement (hypothesis 2)

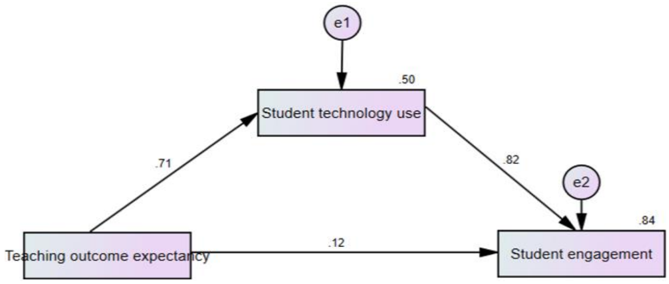

Figure 3. Path diagram of the mediator's role of students' technology use in the relationship between teaching outcome expectancy and students' engagement (hypothesis 3)

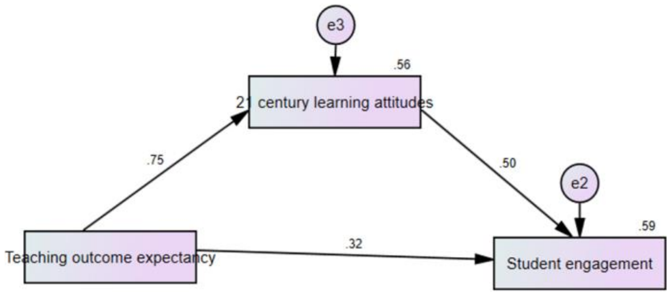

Figure 4. Path diagram of the mediator's role of 21st-century learning attitudes in relationship between teaching outcome expectancy and students' engagement (hypothesis 4)

shown in **Table 3**. All the values in **Table 3** are standardized beta coefficients.

From **Table 3**, it is clear that the prediction of teaching efficacy and beliefs impacts students' technology use significantly, the prediction of teaching efficacy and beliefs impacts students' engagement significantly and the prediction of student technology use impacts students' engagement significantly. It is evident from **Table 3** that the direct path coefficient of .167 is significant. When the mediator is added into the model, the indirect effect has increased to .484 and is significant and the total effect of .651 is significant, hence there is a partial mediating effect of students' technology use on the relationship between teaching efficacy and beliefs and students' engagement. Hypothesis 1 is accepted and it is concluded that students' technology use mediates the relationship between teaching efficacy and beliefs and students' engagement.

From **Table 3**, it is clear that the prediction of teaching efficacy and beliefs impacts 21st-century learning attitudes significantly, the prediction of teaching efficacy and beliefs impacts students' engagement significantly, and the prediction of 21st-century learning attitudes impact students' engagement significantly. It is evident from **Table 3** that the direct path coefficient of .390 is significant. When the mediator is added into the model, the indirect effect has decreased to .238 and is not significant, while the total effect of .628 is significant, hence there is no mediation effect of 21st-century learning attitudes on the relationship between teaching efficacy and beliefs and students' engagement. Hypothesis 2 is rejected and it is concluded that 21st-century learning attitudes do not mediate the relationship between teaching efficacy and beliefs and students' engagement.

From **Table 3**, it is clear that the prediction of teaching outcome expectancy impacts students' technology uses significantly, the prediction of teaching outcome expectancy impacts students' engagement significantly and the prediction of students' technology use impacts students' engagement significantly. It is evident from **Table 3** that the direct path coefficient is .123, which is significant. When the mediator is added to the model, the indirect effect has increased to .581 and is significant. The total effect of .704 is significant, hence there is a partial mediation effect of students' technology use on the relationship between teaching outcome expectancy and students' engagement. Hypothesis 3 is accepted. It is concluded that students' technology use mediates the relationship between teaching outcome expectancy and students' engagement.

From **Table 3**, it is clear that the prediction of teaching outcome expectancy impacts 21st-century learning attitudes significantly, the prediction of teaching outcome expectancy

Table 3. Standardized coefficients of the mediator's role of students' technology use and 21st-century learning attitudes

Variables	β	Direct effect	Indirect effect	Total effect	Decision
Student technology use<---Teaching efficacy & beliefs	.630**	.167*	.484**	.651*	Partial mediation
Student engagement<---Teaching efficacy & beliefs	.167**				
Student engagement<---Student technology use	.769**				
21st-century learning attitudes<---Teaching efficacy & beliefs	.770**	.390*	.238	.628*	No mediation
Student engagement<---Teaching efficacy & beliefs	.390**				
Student engagement<---21st-century learning attitudes	.309*				
Student technology use<---Teaching outcome expectancy	.706**	.123*	.581**	.704**	Partial mediation
Student engagement<---Teaching outcome expectancy	.123**				
Student engagement<---Student technology use	.823**				
21st-century learning attitudes<---Teaching outcome expectancy	.745**	.318**	.373*	.690**	Partial mediation
Student engagement<---Teaching outcome expectancy	.318**				
Student engagement<---21^{st}- century learning attitudes	.500**				

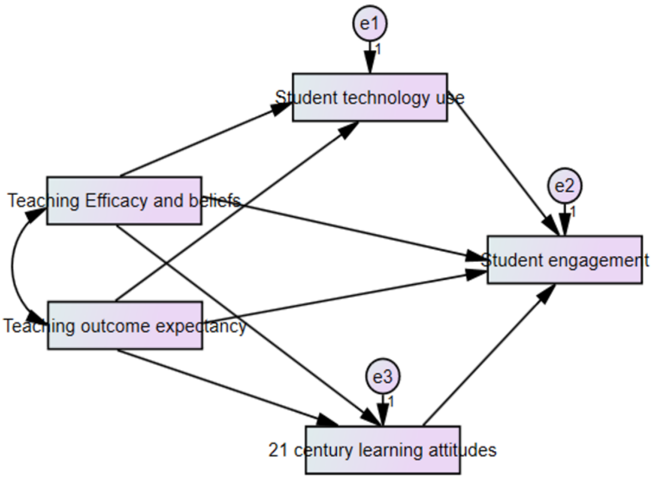

Figure 5. Conceptual model of teaching efficacy and beliefs, teaching outcome expectancy, students' technology use, Students' engagement, and 21st-century learning attitudes

impacts students' engagement significantly, and the prediction of 21st-century learning attitudes impact students' engagement significantly. It is evident from **Table 3** that the direct path coefficient .318 is significant. When the mediator is added to the model, the indirect effect has increased to .373 and is significant. The total effect of .690 is significant, hence there is a mediation effect of 21st-century learning attitudes on the relationship between teaching outcome expectancy and students' engagement. Hypothesis 4 is accepted. It is concluded that 21st-century learning attitudes mediate the relationship between teaching outcome expectancy and students' engagement.

Testing the Conceptual Model

A conceptual model formulated by the authors was tested for model fit in AMOS. The following indices produced by AMOS were used in this study: The Chi-square statistic, which is the test of the absolute fit of the model, GFI, AGFI, NFI, CFI, TLI, PRATIO, and the RMSEA. The results in **Figure 5** indicated a good model fit: $\chi2$=1.513 (p=.219), $\chi2$/df=1.513, GFI=.993, AGFI=.894, NFI=.993, CFI=.998, IFI=.998, RFI=.935, TLI=.977, PCLOSE=.266, and RMSEA=.078. Values for the GFI, AGFI, NFI, IFI, RFI, TLI, and CFI above the 0.90 level indicates a good fit. The RMSEA value of <0.08 was indicative of a moderate fit to confirm the hypothesized model. It is, however, seen that the conceptual model is a moderate fit.

DISCUSSION AND IMPLICATIONS

From the results of the study, it is clear that teaching efficacy and beliefs affect student engagement, and student technology use has a partially mediating effect between them. This finding is supported by previous research findings that teachers' self-efficacy impacts the integration of technology into the classroom. When teachers have high perceptions of their teaching abilities, they would be more confident in integrating technology into the classroom and hence influence students also to explore it (Sadaf & Gezer, 2020). Integration of technology in classrooms provides opportunities for students to explore and gain deeper insights into concepts. Teachers' self-efficacy has an impact on the use of a variety of technological tools and innovative teaching methods (Kim et al., 2013). Such a methodology would influence students to use technology for effective classroom engagement. Schindler et al. (2017) have found that the use of technology in classrooms increases students' engagement. Thus, we can see that teacher efficacy and beliefs as well as student technology use influence students' engagement. Teachers must be trained to integrate technology into classrooms so that they can influence students as well. At the present time, the focus is centered around using technology but the lack of trained teachers to implement them still remains a challenge. Hence, teachers must be provided with opportunities for training to integrate technology. Students must also be provided with opportunities to explore technological tools and use them effectively to support learning. This would increase their engagement in classrooms.

Although 21st-century learning attitudes affect student engagement, the findings show that it does not have a mediating effect on the relationship between teaching efficacy and beliefs and students' engagement. STEM education has been found to impart 21st-century learning attitudes, such as problem-solving, teamwork, and collaboration (Howard-Brown & Martinez, 2012; Orpwood et al., 2012). 21st-century learning attitudes, such as collaboration and teamwork make classroom science learning enjoyable and interesting, thus increasing students' engagement in class (Duran et al., 2011). However, there have been no studies showing the mediation effect of 21st-century learning attitudes on the relationship between teaching efficacy and beliefs and students' engagement. Increasing students' interest in STEM-related activities would help impart 21st-century skills and thereby increase students' engagement in classrooms. Opportunities for problem-solving, collaborative work, projects, and exploration activities in STEM subjects inculcate 21st-century learning attitudes in students. It makes classroom learning meaningful, enjoyable, and enriching learning experience.

STEM education in recent years has gained importance and shown the characteristic of being a popular topic. Teachers' self-efficacy and expectancy beliefs are vital elements for reinforcing students' attitudes and performance, which sheds light on the significance of teachers' roles in student learning. It is seen that teaching outcome expectancy describes teachers' perception that certain actions provide particular outcomes. Classroom resources do not always allow students to fully utilize technology in the classroom. It implies that the impact of certain technologies required for science acquisition in STEM education is still largely speculative, and the instructor faces difficulties in ensuring a meaningful exploration process. Both teachers and students use technology primarily as means for consumers to search for information on the Internet, summarise it and create a presentation, less productively as knowledge creators (Raupp, 2020). The adoption of new technologies is primarily influenced by institutional and individual factors. Technology-enhanced teaching places 21st-century demands on instructors, and teachers' knowledge, experience, and motivation can be viewed as key components in this process. The one with high teaching outcome expectancy would indicate the confidence that effective teaching could overcome the factors, which might compromise students' learning as compared to those who have a low level of teaching outcome expectancy.

Many studies were conducted on STEM education and a few investigated the new approaches (Han et al., 2021). Additionally, it focused on inquiry (DeCoito & Myszkal, 2018) along with the factors that influence STEM learning. According to Bell's (2015) research, STEM studies have increased in the last 10 years. This increase can be due to the discourse of important standards, for instance, International Technology Education Association and National Research Council (2012). As a result, educators from around the world have published international papers in journals about STEM education from a variety of perspectives.

Interactive learning and case studies are the most commonly used STEM teaching strategies, followed by adaptive teaching and E-learning teaching strategies (Kunalan et al., 2018). Despite the fact that the STEM concept is commonly used today, it is clear that the skills that students can develop through STEM education cannot be overstated. STEM education is widely regarded as a broad concept encompassing science, mathematics, technology, and engineering disciplines. It is critical to cultivating the skills that will result from the integration of these disciplines with STEM education. Han et al. (2021) studied in order to outline STEM skills, it examined literature in the form of engineering-based problem solving, establishing interdisciplinary relevance, engineering-based design skills, scientific process skills, life and career skills, creativity, innovation, and digital competence.

In addition to incorporating science, technology, engineering, and mathematics subjects into STEM education, STEM skill development is essential. Inquiry-based instruction cements an important significant impact on the entire school plan by enhancing the scientific achievement of traditionally underperforming students' subgroups in the area of science (Hart, 1909). Professional development is an important theme for both inquiry-based approach and STEM education that includes the development of teachers' competencies, as well as how to plan, evaluate and maintain teachers' collaboration (Dreyøe et al., 2017). Through these, students could develop and improve their knowledge, instructional, and pedagogical skills.

CONCLUSION

The study throws light on the effect of teaching efficacy and beliefs, teaching outcome expectancy, students' technology use, and 21st-century skills on students' engagement in a STEM classroom. It is seen that all these variables affect students' engagement in a classroom with students' technology use having a mediation effect on the relationship between teaching efficacy and beliefs and students' engagement, whereas 21st-century learning attitudes do not have any mediation effect on them. Both students' technology uses and 21st-century learning attitudes have a mediation effect on the relationship between teaching outcome expectancy and students' engagement.

As these factors affect students' engagement in STEM classrooms, instructional strategies and practices that would enhance students' technology use and 21st-century skills must be practiced. For this, teachers must be trained to help students to be accustomed to the effective use of technology and make the most of STEM classes.

Students' attitudes in the direction of STEM content, in addition to their pursuits in STEM careers and their 21st-century skills, can expect students' participation in STEM-related careers. The need to integrate science and engineering practices and help students in real-world problem solving which would, in turn, develop their 21st-century skills is of much importance and teachers must be able to inculcate the same.

Implementing STEM education in the classroom has had a great impact on school boards and it also depends on the professional development courses adopted and adapted by teachers. PDs have been shown to positively impact helping teachers to engage students in a STEM classroom. The need is to integrate subjects rather than learning as different systems help students to understand the applications that these concepts have in the real world.

Regular and sustained PDs and workshops in imparting STEM education help teachers to look at this aspect. PDs must not be limited to just the in-service teachers but must be extended to pre-service teachers too so that they know methodologies that can be adopted and technology that can be integrated for an engaging class. This would help them to practice once they start teaching and would be beneficial in the long run.

However, in implementing them, there are major concerns such as lack of time to prepare. Completing the vast syllabus during the academic year leaves them with no planning and preparation time. The strategies to be adopted and the content pedagogy must be a daily practice that the teachers adopt and must not be seen as different from class activities. The required resources and materials must be made available to teachers to help implement them in daily classroom activities. Teachers must be made aware of the interdisciplinary and integrated nature of STEM rather than subjects working independently. Hence the school management and boards must take the required step to help teachers plan out the schedules and carry out relevant activities that support a STEM classroom.

Limitations and Future Directions

The major limitation of this study is that the convenience sampling technique was used for the purpose of data collection. The sample population was majorly limited to Bengaluru and hence chances of bias was high. The representation of teachers from government schools was low. Hence, the representation from the state-run schools could lead to discrepancies in the study.

Further studies can be implemented by considering a larger and more diverse group of teachers from various parts of the country. Specific factors that can affect teachers' beliefs and attitudes can be examined in detail. An intervention module can be designed and pre and post changes in the attitudes can be studied to evaluate the effect that it can bring about in teachers. Studies on the effects that a STEM classroom can bring about in students is also another area of research that can be examined in depth.

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REFERENCES

al Salami, M. K., Makela, C. J., & de Miranda, M. A. (2015). Assessing changes in teachers' attitudes toward interdisciplinary STEM teaching. *International Journal of Technology and Design Education*, *27*(1), 63-88. https://doi.org/10.1007/s10798-015-9341-0

Aldahmash, A. H., Alamri, N. M., & Aljallal, M. A. (2019). Saudi Arabian science and mathematics teachers' attitudes toward integrating STEM in teaching before and after participating in a professional development program. *Cogent Education*, *6*(1), 1580852. https://doi.org/10.1080/2331186x.2019.1580852

Bandura, A., Freeman, W. H., & Lightsey, R. (1999). Self-efficacy: The exercise of control. *Journal of Cognitive Psychotherapy*, *13*(2), 158-166. https://doi.org/10.1891/0889-8391.13.2.158

Bartels, S. L., Rupe, K. M., & Lederman, J. S. (2019). Shaping preservice teachers' understandings of STEM: A collaborative math and science methods approach. *Journal of Science Teacher Education*, *30*(6), 666-680. https://doi.org/10.1080/1046560x.2019.1602803

Bell, D. (2015). The reality of STEM education, design and technology teachers' perceptions: A phenomenographic study. *International Journal of Technology and Design Education*, *26*(1), 61-79. https://doi.org/10.1007/s10798-015-9300-9

Blotnicky, K. A., Franz-Odendaal, T., French, F., & Joy, P. (2018). A study of the correlation between STEM career knowledge, mathematics self-efficacy, career interests, and career activities on the likelihood of pursuing a STEM career among middle school students. *International Journal of STEM Education*, *5*, 22. https://doi.org/10.1186/s40594-018-0118-3

Booher, L., Nadelson, L. S., & Nadelson, S. G. (2020). What about research and evidence? Teachers' perceptions and uses of education research to inform STEM teaching. *The Journal of Educational Research*, *113*(3), 213-225. https://doi.org/10.1080/00220671.2020.1782811

Breiner, J. M., Harkness, S. S., Johnson, C. C., & Koehler, C. M. (2012). What is STEM? A discussion about conceptions of STEM in education and partnerships. *School Science and Mathematics*, *112*(1), 3-11. https://doi.org/10.1111/j.1949-8594.2011.00109.x

Caprara, G. V., Barbaranelli, C., Steca, P., & Malone, P. S. (2006). Teachers' self-efficacy beliefs as determinants of job satisfaction and students' academic achievement: A study at the school level. *Journal of School Psychology*, *44*(6), 473-490. https://doi.org/10.1016/j.jsp.2006.09.001

Darling-Hammond, L., Flook, L., Cook-Harvey, C., Barron, B., & Osher, D. (2019). Implications for educational practice of the science of learning and development. *Applied Developmental Science*, *24*(2), 97-140. https://doi.org/10.1080/10888691.2018.1537791

Davison, D. M., Miller, K. W., & Metheny, D. L. (1995). What does integration of science and mathematics really mean? *School Science and Mathematics*, *95*(5), 226-230. https://doi.org/10.1111/j.1949-8594.1995.tb15771.x

DeCoito, I., & Myszkal, P. (2018). Connecting science instruction and teachers' self-efficacy and beliefs in STEM education. *Journal of Science Teacher Education*, *29*(6), 485-503. https://doi.org/10.1080/1046560x.2018.1473748

Dreyøe, J., Larsen, D. M., Hjelmborg, M. D., Michelsen, C., & Misfeldt, M. (2017). *Inquiry-based learning in mathematics education: Important themes in the literature* [Paper presentation]. Norma 2017, Stockholm, Sweden.

Duran, E., Yaussy, D., & Yaussy, L. (2011). Race to the future: Integrating 21st century skills into science instruction. *Science Activities: Classroom Projects and Curriculum Ideas*, *48*(3), 98-106. https://doi.org/10.1080/00368121.2010.535222

English, L. D. (2016). STEM education K-12: Perspectives on integration. *International Journal of STEM Education*, *3*, 3. https://doi.org/10.1186/s40594-016-0036-1

FIEI. (2012). *Teacher efficacy and attitudes toward STEM survey–Mathematics teachers*. Friday Institute for Educational Innovation.

Gardner, K., Glassmeyer, D., & Worthy, R. (2019). Impacts of STEM professional development on teachers' knowledge, self-efficacy, and practice. *Frontiers in Education*. https://doi.org/10.3389/feduc.2019.00026

Geng, J., Jong, M. S. Y., & Chai, C. S. (2018). Hong Kong teachers' self-efficacy and concerns about STEM education. *The Asia-Pacific Education Researcher*, *28*(1), 35-45. https://doi.org/10.1007/s40299-018-0414-1

Hackman, S. T., Zhang, D., & He, J. (2021). Secondary school science teachers' attitudes towards STEM education in Liberia. *International Journal of Science Education*, *43*(2), 223-246. https://doi.org/10.1080/09500693.2020.1864837

Han, J., Kelley, T., & Knowles, J. G. (2021). Factors influencing student STEM learning: Self-efficacy and outcome expectancy, 21st century skills, and career awareness. *Journal for STEM Education Research*, *4*(2), 117-137. https://doi.org/10.1007/s41979-021-00053-3

Hart, J. K. (1909). Moral instruction and training in the schools. The report of an international inquiry. M. E. Sadler. *The Elementary School Teacher*, *9*(6), 333-334. https://doi.org/10.1086/453850

Herschbach, D. R. (2011). The STEM initiative: Constraints and challenges. *Journal of STEM Teacher Education*, *48*(1), 96-122. https://doi.org/10.30707/jste48.1herschbach

Holmlund, T. D., Lesseig, K., & Slavit, D. (2018). Making sense of "STEM education" in K-12 contexts. *International Journal of STEM Education*, *5*, 32. https://doi.org/10.1186/s40594-018-0127-2

Hourigan, M., O'Dwyer, A., Leavy, A. M., & Corry, E. (2021). Integrated STEM–A step too far in primary education contexts? *Irish Educational Studies*. https://doi.org/10.1080/03323315.2021.1899027

Howard-Brown, B., & Martinez, D. (2012, May). *Engaging diverse learners through the provision of STEM education opportunities*. Briefing Paper (No. ED573497), SEDL, Southeast Comprehensive Centre, U.S. Department of Education.

Kim, C., Kim, M. K., Lee, C., Spector, J. M., & DeMeester, K. (2013). Teacher beliefs and technology integration. *Teaching and Teacher Education*, *29*, 76-85. https://doi.org/10.1016/j.tate.2012.08.005

Klassen, R. M., Foster, R. Y., Rajani, S., & Bowman, C. (2009). Teaching in the Yukon: Exploring teachers' efficacy beliefs, stress, and job satisfaction in a remote setting. *International Journal of Educational Research*, *48*(6), 381-394. https://doi.org/10.1016/j.ijer.2010.04.002

Koc Akran, S., & Asiroglu, S. (2018). Perceptions of teachers towards the STEM education and the constructivist education approach: Is the constructivist education approach preparatory to the STEM education? *Universal Journal of Educational Research*, *6*(10), 2175-2186. https://doi.org/10.13189/ujer.2018.061016

Kunalan, A., Cheah, P. K., Moses, P., Er, P. H., & Ng, C. A. (2018). Teaching strategies employed by academics in STEM education: A qualitative iquiry. *E3S Web of Conferences*, *65*, 04002. https://doi.org/10.1051/e3sconf/20186504002

Larson, J. S., & Farnsworth, K. (2020). Crisis teaching online: Reaching K-12 students through remote engineering lab-based activities during the COVID-19 pandemic. *Advances in Engineering Education*, *8*(4), 1-9.

Lee, O., & Campbell, T. (2020). What science and STEM teachers can learn from COVID-19: Harnessing data science and computer science through the convergence of multiple STEM subjects. *Journal of Science Teacher Education*, *31*(8), 932-944. https://doi.org/10.1080/1046560x.2020.1814980

Lemon, N., & Garvis, S. (2015). Pre-service teacher self-efficacy in digital technology. *Teachers and Teaching*, *22*(3), 387-408. https://doi.org/10.1080/13540602.2015.1058594

Luo, T., So, W. W. M., Wan, Z. H., & Li, W. C. (2021). STEM stereotypes predict students' STEM career interest via self-efficacy and outcome expectations. *International Journal of STEM Education*, *8*, 36. https://doi.org/10.1186/s40594-021-00295-y

Malti, D. (2017). Need and importance of STEM education in Indian schools. *PARIPEX–Indian Journal of Research*, *6*(1), 852-853.

Margot, K. C., & Kettler, T. (2019). Teachers' perception of STEM integration and education: A systematic literature review. *International Journal of STEM Education*, *6*, 2. https://doi.org/10.1186/s40594-018-0151-2

Muijs, D., & Reynolds, D. (2002). Teachers' beliefs and behaviors: What really matters? *The Journal of Classroom Interaction*, *37*(2), 3-15.

Murphy, S., MacDonald, A., Wang, C. A., & Danaia, L. (2019). Towards an understanding of STEM engagement: A review of the literature on motivation and academic emotions. *Canadian Journal of Science, Mathematics and Technology Education*, *19*(3), 304-320. https://doi.org/10.1007/s42330-019-00054-w

Nadelson, L. S., & Seifert, A. L. (2017). Integrated STEM defined: Contexts, challenges, and the future. *The Journal of Educational Research*, *110*(3), 221-223. https://doi.org/10.1080/00220671.2017.1289775

Nadelson, L. S., Seifert, A. L., & Sias, C. (2015). To change or not to change: Indicators of K-12 teacher engagement in innovative educational practices. *International Journal of Innovation in Education*, *3*(1), 45. https://doi.org/10.1504/ijiie.2015.074704

National Research Council. (2012). *A framework for K-12 science education: Practices, crosscutting concepts, and core ideas*. National Academies Press.

Orpwood, G., Schmidt, B., & Jun, H. (2012). Competing in the 21st century skills race. *Canadian Council of Chief Executives*. https://thebusinesscouncil.ca/app/uploads/2012/07/Competing-in-the-21st-Century-Skills-Race-July-2012.pdf

Ottenbreit-Leftwich, A. T., Glazewski, K. D., Newby, T. J., & Ertmer, P. A. (2010). Teacher value beliefs associated with using technology: Addressing professional and student needs. *Computers & Education, 55(3)*, 1321-1335. https://doi.org/10.1016/j.compedu.2010.06.002

Pagar, R. (2018). Why STEM education is necessary in the Indian education sector. *The Hindu*. https://www.thehindu.com/education/nurturing-innovators/article23279020.ece

Park, H. J., Byun, S. Y., Sim, J., Han, H. S., & Baek, Y. S. (2016). Teachers' perceptions and practices of STEAM education in South Korea. *EURASIA Journal of Mathematics, Science and Technology Education*, *12*(7), 1739-1753. https://doi.org/10.12973/eurasia.2016.1531a

Raupp, A. B. (2020). Innovation in STEM education critical to make in India's success. *Medium*. https://medium.datadriveninvestor.com/innovation-in-stem-education-is-critical-to-make-in-indias-continued-success-b3ab81c38ad9

Riggs, I. M., & Enochs, L. G. (1990). Toward the development of an elementary teacher's science teaching efficacy belief instrument. *Science Education*, *74*(6), 625-637. https://doi.org/10.1002/sce.3730740605

Ring, E. A., Dare, E. A., Crotty, E. A., & Roehrig, G. H. (2017). The evolution of teacher conceptions of STEM education throughout an intensive professional development experience. *Journal of Science Teacher Education*, *28*(5), 444-467. https://doi.org/10.1080/1046560x.2017.1356671

Sadaf, A., & Gezer, T. (2020). Exploring factors that influence teachers' intentions to integrate digital literacy using the decomposed theory of planned behavior. *Journal of Digital Learning in Teacher Education*, *36*(2), 124-145. https://doi.org/10.1080/21532974.2020.1719244

Sawyer, A. G., & Myers, J. (2018). Seeking comfort: How and why preservice teachers use internet resources for lesson planning. *Journal of Early Childhood Teacher Education*, *39*(1), 16-31. https://doi.org/10.1080/10901027.2017.1387625

Schindler, L. A., Burkholder, G. J., Morad, O. A., & Marsh, C. (2017). Computer-based technology and student engagement: A critical review of the literature. *International Journal of Educational Technology in Higher Education*, *14*, 25. https://doi.org/10.1186/s41239-017-0063-0

Schweingruber, H., Pearson, G., & Honey, M. (2014). *STEM Integration in K-12 education: Status, prospects, and an agenda for research* (Illustrated ed.). National Academies Press. https://doi.org/10.17226/18612

Sharma, J., & Yarlagadda, P. K. (2018). Perspectives of 'STEM education and policies' for the development of a skilled workforce in Australia and India. *International Journal of Science Education*, *40*(16), 1999-2022. https://doi.org/10.1080/09500693.2018.1517239

Skaalvik, E. M., & Skaalvik, S. (2010). Teacher self-efficacy and teacher burnout: A study of relations. *Teaching and Teacher Education*, *26*(4), 1059-1069. https://doi.org/10.1016/j.tate.2009.11.001

So, W. M. W., He, Q., Chen, Y., & Chow, C. F. (2020). School-STEM professionals' collaboration: A case study on teachers' conceptions. *Asia-Pacific Journal of Teacher Education*, *49*(3), 300-318. https://doi.org/10.1080/1359866x.2020.1774743

Verma, R. (2021). National education policy & STEM. *STEM FOR YOU*. https://stemforyou.com/national-education-policy-stem/

VIF. (2019). Towards more effective education: Emergence of STEM education in India (No. 13-148). *Vivekananda International Foundation*. https://www.vifindia.org/paper/2019/march/26/towards-more-effective-education-emergence-of-stem-education-in-india

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*, 36. https://doi.org/10.1186/s40594-020-00236-1

Wang, H.-H., Moore, T. J., Roehrig, G. H., & Park, M. S. (2011). STEM integration: Teacher perceptions and practice. *Journal of Pre-College Engineering Education Research*, *1*(2), 1-13.

Yildirim, B. (2020). MOOCs in STEM education: Teacher preparation and views. *Technology, Knowledge and Learning*. https://doi.org/10.1007/s10758-020-09481-3