Open access • Journal Article • DOI:10.1007/S10798-017-9416-1

How school context and personal factors relate to teachers' attitudes toward teaching integrated STEM — Source link

Lieve Thibaut, Heidi Knipprath, Wim Dehaene, Fien Depaepe

Institutions: Katholieke Universiteit Leuven

Published on: 01 Sep 2018 - International Journal of Technology and Design Education (Springer Netherlands)

Topics: Science education, Teaching method, Competence (human resources) and Faculty development

How school context and personal factors relate to teachers' attitudes toward teaching integrated STEM.

Lieve Thibaut, Heidi Knipprath, Wim Dehaene, Fien Depaepe

Abstract

Integrated STEM (Science, Technology, Engineering and Mathematics) education is an emerging approach to improve students' achievement and interest in STEM disciplines. However, the implementation of integrated STEM education depends strongly on teachers' competence, which entails, among others, teachers' attitudes. Nonetheless, not much is known about the factors that influence teachers' attitudes toward teaching integrated STEM. Therefore this paper uses a survey method to get insight into the relationship between three groups of variables and teachers' attitudes toward teaching integrated STEM: teacher background characteristics, personal attitudes and school context variables. The results of the multiple regression analyses reveal three variables that are positively linked with teachers' attitudes: professional development, personal relevance of science and social context. Moreover two variables show a negative correlation: having more than 20 years of teaching experience and experience in mathematics. The results of this study provide valuable information about factors related to teachers' attitudes toward teaching integrated STEM. Moreover, these results can be deployed by school administrators to guide them when composing a team of teachers to implement integrated STEM education.

Keywords: attitudes; survey; secondary education; STEM; teachers;

Introduction

The current shortage of graduates in the fields of Science, Technology, Engineering and Mathematics (STEM) calls for new strategies to promote students' choice of STEM careers (Fox & Hackerman 2002; Lee 2015; Wang 2013a). Since this choice was found to be strongly influenced by students' achievement in STEM disciplines (Goldsmith, Tran & Tran 2014; Nugent, Barker, Grandgenett & Adamchuk 2010), their self-efficacy beliefs in STEM (Maltese & Tai 2011; Wang 2013b) and personal interest (Hall, Dickerson, Batts, Kauffman & Bosse 2011), educational reforms should target these features. A promising approach in this regard, is the use of an integrated curriculum (Czerniak, Weber, Sandmann, & Ahern 1999). Studies in a broad range of disciplines have shown that students involved in an integrated curriculum perform as well or even better than their peers in traditional instruction with separate disciplines (Bragow, Gragow & Smith 1995; McComas 1993; McComas & Wang 1998; Savasa, Senemoglub & Kocabas 2012). Savasa et al. (2012) investigated the use of an integrated unit in social studies class and observed significant differences in the scores for academic achievement, attitude and academic self-confidence in favour of the experimental group. Friend (1985) examined the effect of an integrated science and mathematics physics unit on seventh grade students and found that students involved in the integrated unit achieved better than similar students in the non-integrated format. McComas and Wang (1998) summarized several studies of college-age students that demonstrated greater achievement or interest in science when science was presented as an integrated program rather than a traditional sequence. Moreover, other researchers (e.g. Bragow, Gragow & Smith 1995; McComas 1993) demonstrated that integrated units had a positive impact on students' attitudes and motivation.

When integrating science, mathematics and technology, this approach is called 'integrated STEM education'. The term refers to learning environments in which teams of students participate in engineering design and/or research and experience meaningful learning through integration and application of mathematics, technology and/or science (Moore & Smith 2014).

Nonetheless, the deployment of integrated STEM education in the classroom does not always go smoothly, since teacher education programs rarely offer pre-service teachers courses in which they experience learning that integrates multiple disciplines (Roebuck & Warden 1998). Several researchers found that the implementation of new instructional practices, such as integrated STEM education, is strongly dependent on teachers' attitudes (Gregoire, 2003, Pintó, 2005; Roehrig, Kruse & Kern, 2007). Therefore, this paper focuses specifically on. teachers' attitudes toward teaching integrated STEM. The goal of the study is to provide further insight in the variables related to these attitudes. The investigated variables can be categorized in three groups: teacher background characteristics, school context variables and teachers' personal attitudes toward STEM.

Theoretical Background

Definition of integrated STEM education

Integrated STEM education is an instructional approach in which students participate in engineering design and/or research and experience meaningful learning through integration and application of mathematics, technology and/or science (Moore & Smith 2014). An important aspect of integrated STEM education is technology education. Technology education differs from simply using technology since it is 'concerned with developing knowledge of technology and technological artefacts, and technological skills for students along with technological literacy' (Sade & Coll, 2003, p.89). Technology education is especially useful as it plays a critical role in establishing authentic contexts and problems, which is –as explained below- a defining aspect of integrated STEM education (Herrington & Kervin 2007).

STEM integration is inextricably linked to the theory of social constructivism, which emphasizes the idea that knowledge cannot be transmitted, but rather is actively constructed by the learner while solving meaningful problems (Jonassen 1999). Construction of knowledge takes place through direct interaction with other learners and within the specific constraints and affordances of the problem context (Brown, Collins & Duguid 1989; Rieber 1993).

By combining critical elements from both the theory of social constructivism and the empirical evidence found by several researchers (Honey, Pearson & Schweingruber 2014; Froyd 2008; Moore & Smith, 2014; Pinnell, Rowly, Preiss, Franco, Blust & Beach 2013; Zemelman, Daniels & Hyde 2005), five key features of integrated STEM education (hereafter denoted as STEM principles) were defined. The first principle, integration of STEM content, refers to the alignment of content from different courses (Choi & Pak 2006; Drake & Burns 2004; Pettus 1994). Traditionally, alignment entails the connection between learning objectives, learning activities and assessment within a course (Streveler, Smith & Pilotte 2012). Therefore, when used within the context of integrated STEM, this term designates the connection between learning objectives, learning activities and assessment across different STEM courses. The second principle, problem-centered learning, indicates that learning environments should involve students in relevant and authentic problems to increase the meaningfulness of learning (Christensen, Knezek & Tyler-Wood 2015; Gottfried 2015). Regarding the meaning of 'authentic', different perspectives exist (Turnbull 2002). According to Hennessy and Murphy (1999) 'authentic' or 'real' might mean either real and relevant to students own lives or real to situations that they may encounter in the future workplace. In this framework for integrated STEM education, both perspectives are taken into account. Inquiry-based learning, the third principle, refers to learning that is driven by questioning, thoughtful investigating, making sense of information and developing new understandings (Diggs, 2009). For example in science, students have to plan and design experiments, collect data and reflect on the results by providing explanations for scientific phenomena (Capps & Crawford 2013), while in mathematics learners have to question, challenge, discuss, interpret and explore mathematical ideas (Menmuir & Adams 1997). Similarly, the principle of design-based learning advocates the active engagement of learners in creating some type of external artifact (e.g., a robot or a computer program), because learners are more inclined to construct new ideas when they are actively engaged in designing (Kafai & Resnick 1996). Finally, the principle of cooperative learning indicates that students should be given the opportunity to communicate and collaborate with each other to deepen their knowledge (Christensen et al. 2015).

Implementation of integrated STEM education

The implementation of integrated STEM education depends on the behaviour of the teachers, since they are responsible for selecting the appropriate instructional methods. According to the Social Cognitive Theory (SCT) of Bandura (1986), behaviour is linked with personal factors and environmental influences, which operate as bi-directionally interacting elements (Bandura 1989). Therefore, future behaviour is a function of three interrelated forces: environmental influences, a person's current and past behaviour, and internal personal factors such as cognitive abilities, attitudes and background characteristics (Henson 2001). This relationship is shown in Figure 1.

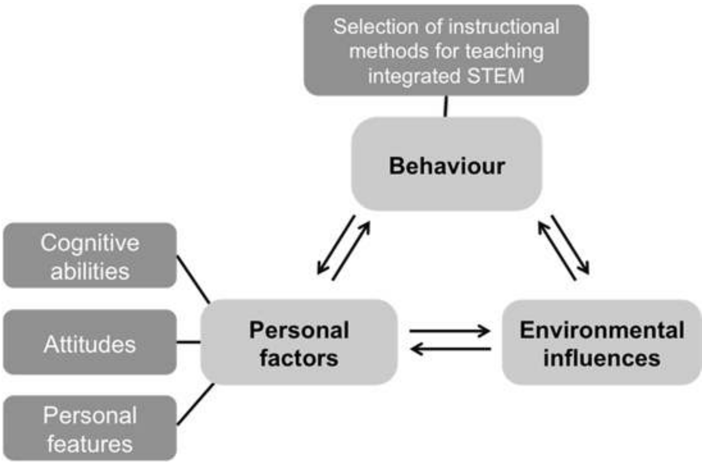


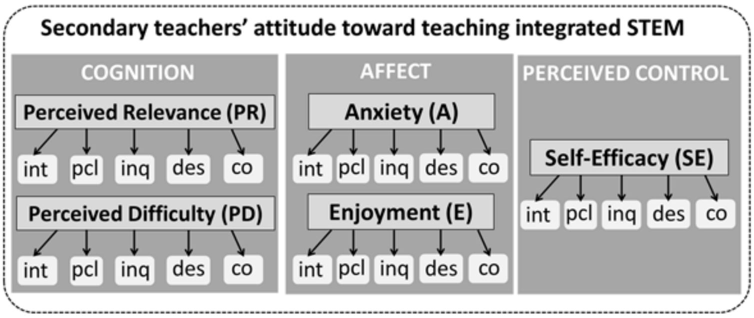
Fig. 1 Representation of the Social Cognitive theory (SCT) as introduced by Bandura (1986)

While research has focused on the role of teachers' cognitive abilities in the implementation of integrated STEM education (e.g., Hudson, English, Dawes, King & Baker 2015), this study focuses on teachers' attitudes. Attitudes are claimed to guide teachers in their actual classroom practices and play a fundamental role in the acceptance of new approaches, techniques, and activities (Donaghue 2003). In other words, changes in teachers' practices can be the consequence of alteration in their attitudes (Borg 2011; Mansour 2009; Polat 2010).

Teacher attitudes

Since no general agreement about the definition of 'attitude' exists, in this paper, the term is used to refer to the psychological tendency to classify an object in terms of favorable or unfavorable dimensions (e.g. good/bad or pleasant/unpleasant) (Ajzen 2001; Eagly & Chaiken 1993). Two terms in this definition need further clarification: 'object' and 'dimensions'. Depending on the object, a distinction can be made between the personal attitudes of teachers toward STEM and their professional attitudes toward the *teaching* of (integrated) STEM. Personal attitudes toward STEM refer to the attitudes of a person independent of his profession and include beliefs about the relevance of science, mathematics and technology for society or daily life. In contrast, teachers' professional attitudes toward teaching integrated STEM involve the ideas and feelings that teachers may have with respect to teaching these topics within the school context (van Aalderen-Smeets, van der Molen & Asma 2012). It is assumed that professional attitude toward teaching integrated STEM is a stronger predictor of actual teaching behavior than teachers' personal attitude towards STEM, because of the more direct link to actual STEM teaching (van Aalderen□Smeets & van der Molen, 2015). Nonetheless, improvements in personal attitude toward STEM presumably will positively influence improvements in professional attitude. Therefore, although the importance of personal attitudes is not discarded, in this paper, the focus will be on teachers' professional attitudes, whereas personal attitudes are seen as a variable that can influence these professional attitudes. Next to 'object', the second term in the definition of attitude that needs explanation is 'dimensions'. To specify these dimensions, usually the Three-Component-Definition of attitude is used (Pratkanis, Breckler & Greenwald 2014). This definition distinguishes three components: a cognitive component, which encompasses a person's thoughts and opinions about the attitude object; an affective component, which consists of feelings a person experiences in relation to the attitude object; and a behavioural component, which constitutes the actions of a person when confronted with the attitude object (Eagly & Chaiken, 1993).

To gain insight in the specific dimensions of interest and subscales of teachers' attitudes, van Aalderen-Smeets and colleagues (2012) built a framework for primary teachers' attitudes toward teaching science. By combining this framework with the integrated STEM principles, a framework for teachers' attitude toward teaching integrated STEM was developed from prior research (Figure 2).



Int= Integration of STEM content; **pcl**= Problem-centered learning; **inq**= inquiry-based learning; **des**= design-based learning; **co**= cooperative learning

Fig. 2 Theoretical framework for teachers' attitudes toward teaching integrated STEM

This framework consists of two cognitive subscales: (a) opinions about the relevance and importance of teaching integrated STEM, and (b) ideas about the difficulty that is attributed to the task of teaching integrated STEM by teachers in general. Furthermore, two subscales referring to teachers' feelings or affective states were determined: (a) enjoyment and (b) anxiety in teaching integrated STEM. Finally, one subscale constitutes the dimension of perceived control: self-efficacy or a person's beliefs about control over internal factors such as knowledge, confidence and skills. Unlike the Three-Component-Definition of attitude, behaviour is not specified as a component of attitude in this framework. Rather, behaviour is perceived as an element arising from a person's attitude, which coincides with the way behaviour is perceived in the Social Cognitive Theory as explained above.

Factors affecting teachers' attitudes toward teaching integrated STEM

Since teachers' (professional) attitudes influence their professional behaviour and therefore the implementation of integrated STEM education, it is important to gain an understanding of the prevalence of certain attitudes in STEM teachers. Social Cognitive Theory indicates that the environment has an influence on teachers' attitudes. Therefore, the relationship between teachers' attitudes and school context is investigated. However, there might also be other characteristics, for example teachers' background characteristics that have a significant influence on their attitudes.

To identify factors that generate significant differences in teachers' attitudes, it is useful to take a look at the sources of these attitudes. However, various sources underlie teachers' attitudes and there is no consensus among researchers (Mellati, Khademi & Shirzadeh 2014). Some researchers claim that attitudes derive from sources such as personality and teaching experiences (Donaghue 2003; Kagan 1992, Zeichner and Tabachnick 1981). Other researchers stress the importance of teacher education programs in shaping teachers' attitudes (Finsterwald, Wagner, Schober, Lüftenegger, & Spiel 2013; Kennedy and Smith 2013). Finally, teachers' own schooling as young students and observing their own teachers are named as sources of teachers' attitudes (Levin and He 2008). In an effort to theoretically underpin these experiences, Bandura (1977) distinguished four kinds of experiences that could affect a person's level of self-efficacy: (a) mastery experiences, (b) vicarious experience, (c) social persuasion, and (d) emotional arousal. *Mastery experiences* are situations in which teachers are actively involved in the desired teaching behavior. If these teaching activities are consistently successful, they tend to raise self-efficacy. Likewise, if these activities typically produce failure, self-efficacy is likely to be lowered. *Vicarious experience* is learning from observation of the successes of other teachers. *Social persuasion* happens when credible people (e.g. colleagues and superiors) convince a teacher of his/her capabilities to teach successfully. Finally, *emotional states* refer to the influence of feelings on behaviour. If a teacher experiences stress or fear when teaching, this can lead to negative judgements about his/her ability to teach (Webb, 2015).

To further investigate the origin of teachers' attitudes, Collinson (2012) asked 81 exemplary secondary school teachers across the USA to indicate what they perceived as the sources of their attitudes. This way, fourteen possible sources were found of which some belong in the category 'school context' (e.g., colleagues, politics and leadership) and others are discerned as 'teacher background characteristics' (e.g., prior career, use). However, since no distinction was made between personal and professional attitudes, some of the sources mentioned by the participants are personal (e.g., life's routine, traumatic events, religion) and seem less relevant in the development of professional attitudes. Nonetheless, the personal attitudes a teacher holds about the usefulness or relevance of science, technology and mathematics in everyday life might influence his or her professional attitudes. Therefore this third category is added. Next, variables within the three categories (background characteristics, school context and personal attitudes) are briefly discussed.

Teacher background characteristics

Finding predictive factors of teachers' attitudes equals the determination of background characteristics that cause teachers to undergo a varying degree of mastery, vicarious, socially persuasive and/or emotional arousing experiences. Table 1 lists the background characteristics taken into account in this study. The selection of these variables was based on the sources defined by Collinson (2012). For each of the background characteristics, the respective kind of experience as defined by Bandura (1977) was added. Selection of these respective experiences was based on the research of Crook (2016).

Table 1 Background variables and their respective sources of attitude

Background characteristic	**Source of attitude according to Collinson (2012)**	**Kind of experience according to Bandura (1977)**
1. Master diploma	Teachers or role models	Vicarious experience Mastery experience
2. Professional Development	Intensive professional development	Mastery experience Vicarious experience
3. Experience with teaching of Integrated STEM 4. Years of teaching 5. Experience in Physics 6. Experience in Engineering **7. Experience in Mathematics** **8. Experience in Technology**	Experimental or accidental use	Mastery experience Vicarious experience
9. Non-teaching work experience	Prior Career	Mastery experience Vicarious experience Social persuasion Emotional arousal
10. Gender	///	Social persuasion Emotional arousal

The first background characteristic refers to teachers' educational level and more specifically whether or not they possess a *master (or graduate) diploma*. Students spend years observing teachers. Therefore teachers represent a major source of attitudes in the form of vicarious experience (Lortie 1975). Since instructional methods (e.g., the degree of active involvement of the students) differ according to the educational level (e.g., Jarski, Kulig & Olson 1990), this background characteristic can result in different attitudes. For example, teachers with a graduate (or masters) degree have been found to have higher levels of teacher self–efficacy than teachers with undergraduate (or bachelor) education (Hoover–Dempsey, Bassler, & Brissie 1987)

The second background characteristic refers to participation in *professional development*, which is an important provider of vicarious experiences (Mizell 2008). A small number of studies have investigated this relationship (e.g., Powell-Moman & Brown-Schild 2011; Ross & Bruce 2007) and concluded that when teachers actively participate in quality professional development opportunities, their self-efficacy increases.

Five background characteristics can be attributed to the category 'Experimental or accidental use' as defined by Collinson (2012). This category represents doing something intentional or unintentional that alters attitudes and then repeating what appears successful or avoiding what is unsuccessful. Therefore this coincides with the term 'mastery experiences' used by Bandura (1977).

The first background characteristic in this category refers to a teacher's *experience in teaching an integrated STEM course*. Teachers who are actively involved in such a course get the opportunity to gain hands-on experience (i.e. mastery experience). Moreover, often co-teaching or team teaching is used when implementing integrated STEM education. When this is the case, teachers can also observe fellow teachers and therefore gain vicarious experience. Since these experiences differ from teachers who are not involved in an integrated STEM course, a difference in attitude between both groups can occur.

Another factor that is taken into account is *years of teaching*. Teachers, who have been in the field longer, have gained more mastery experiences compared to novice teachers and would therefore exhibit altered attitudes (Bandura 1997). However, research regarding the difference in attitude between new and experienced teachers has led to conflicting results (Tweed 2013). Therefore, researchers suggest that self-efficacy fluctuates over the course of a teaching career: teachers increase in self- efficacy through their early years and into the mid-career years but can decrease in efficacy as they enter the last stages of their careers (Klassen & Chiu 2010).

The next four variables refer to experience in specific subjects (physics, engineering, mathematics and technology). Some researchers (e.g., Ginns, Watters, Tulip, & Lucas 1995; Ramey-Gassert, Shroyer, & Staver 1996) claim that teachers' attitudes may be domain specific since tasks and situations of teaching are to a large extent shaped by the nature of the subject the teacher teaches (Chen & Yeung 2015). However, until now, only limited research has focused on teacher self-efficacy within particular subjects.

A final characteristic, which was not named by Collinson (2012), but which has been profoundly studied in regard to its possible influence on attitudes is the *gender* of the teacher. According to Hackett and Betz (1981), male and female teachers can have different levels of self-efficacy in a given domain due to differential access of girls and boys to the four proposed sources of attitudes. However studies regarding the influence of gender on teachers' attitudes proved conflicting. While some studies found that females report higher teacher self-efficacy than males (Andersen 2011; Anderson, Greene, & Lowen 1988; Raudenbush, Rowan, & Cheong 1992), other studies reported the opposite (e.g., Eccles, 1994; Hackett 1985) and still other researchers found no differences in teacher self-efficacy by gender at all (Lee, Dedrick, & Smith 1991).

School context variables

According to the social cognitive theory (Bandura, 1986), teachers' attitudes can be influenced by the environment (Nespor 1987). Appleton and Kindt (1999) asked teachers to indicate which context factors would make it harder or easier for them to teach science and found four main factors: collegial support, lack of resources (materials and examples), time allocated for science in the curriculum, and the time and effort needed to prepare science lessons. Lumpe, Haney, and Czerniak (2000) asked respondents about the perceived influence of potential context factors from five different categories: standardized teaching methods and curriculum, social support, resources (materials and money), time available within the curriculum, and preparation time. The school context variables taken into account in this study and their link with the factors found by Lumpe et al. (2000) are given in Table 2.

Table 2 School context variables and their respective sources of attitude

Background characteristic	Category by Lumpe et al. (2000)
Clear curriculum objectives for your STEM course Ready-made teaching materials	Standardized teaching methods and curriculum
Content support by colleagues Professional development Clear vision of the management board about STEM education Cooperation with other STEM teachers Technical support by "experts"	Social support

Budget Technical material Adjusted classrooms Logistical support Small classes (= number of students)	Resources (materials and money)
Sufficient teaching hours	Time available within the curriculum

Personal attitudes toward STEM

Van Aalderen-Smeets et al. (2012) differentiate between teachers' professional attitudes, which refer to teachers' attitudes toward teaching integrated STEM, and their personal attitudes, which refer to their attitudes about STEM in their personal life. Since it is likely that personal attitudes about the relevance of STEM influence their professional attitudes, these are also taken into account. Within the field of integrated STEM, very little research has been undertaken to understand attitudes of teachers, since this requires an accurate definition of integrated STEM and a valid tool for measuring teachers' attitudes toward it. Even less is known about factors that could influence teachers' attitudes toward teaching integrated STEM. Therefore this paper aims at providing further insight into the background characteristics, personal attitudes and school context variables related to these attitudes. The research question that is addressed in this paper is: 'How can differences in secondary teachers' professional attitudes toward teaching integrated STEM be explained by teachers' background characteristics, personal attitudes toward STEM and school context factors?'

Method

As there is only limited research regarding teachers' attitudes toward integrated STEM, this study is exploratory in nature and does not aim at verifying hypotheses. The main goal is to elicit factors related to teachers' attitudes toward teaching integrated STEM. Three groups of factors are taken into account: personal background characteristics, teachers' personal attitudes toward STEM and school context variables. To achieve this, a survey research method was employed.

Sample and procedure

All questionnaires were administered online in the period between October 2015 and December 2015 among 30 schools participating in a research project about integrated STEM education. The questionnaire took about 20 minutes to complete and filling in the questionnaire was voluntary. In total, 135 secondary teachers in the fields of mathematics, engineering, science and technology responded to the questionnaire. Of these 135 teachers 51 (37.8 %) taught integrated STEM, while 84 (62.2 %) taught a core subject related to only one of the STEM domains. The participants were slightly more female (58.5%) with a mean age of 42 years (range 23–63 years). Other descriptive variables of the participants are given in Table 3.

Table 3 Teacher Background characteristics including Descriptive statistics of the sample of participants

Name	Description	Scale	Percentage
Integrated STEM	Indicates if the teacher is involved in teaching an integrated STEM course.	0 = No 1= Yes	 37.8
Female	Gender of the teacher.	0 = Male 1 = Female	 58.5
Master	Indicates if the teacher has obtained a masters' degree.	0 = No 1 = Yes	 49.6
Professional Development	Indicates if the teacher has participated in STEM-related professional development in the last year.	0 = No 1 = Yes	40.0
Years of teaching	Total teaching experience of the teacher (in years)	1 = 1-5 years 2 = 6-10 years	17.6 12.2

		3 = 11-15 years 4 = 16-20 years 5 = > 20 years	18.3 13.0 38.9
Non-teaching work experience	Indicates if the teacher has work experience in a non-teaching context.	0 = No 1 = Yes	22.2
Experience in Physics	Indicates if the teacher has experience with teaching physics.	0 = No 1 = Yes	15.6
Experience in Engineering	Indicates if the teacher has experience with teaching engineering.	0 = No 1 = Yes	56.3
Experience in Mathematics	Indicates if the teacher has experience with teaching mathematics.	0 = No 1 = Yes	58.5
Experience in Technology	Indicates if the teacher has experience with teaching technology	0 = No 1 = Yes	44.5

Measures of attitudes toward teaching integrated STEM

In determining secondary teachers' attitudes toward teaching integrated STEM a questionnaire based on the theoretical framework (see Figure 2) was developed. Questions were developed for each of the 25 categories, leading to a total of 107 items. Respondents were asked to indicate their level of agreement with these items on a 5-point Likert-scale (1= totally disagree, 5= totally agree). To confirm construct validity of the questionnaire both Exploratory Factor Analysis (EFA) and Confirmatory Factor Analysis (CFA) were performed. In addition, the reliability was tested by computing the Cronbach's alpha coefficient of each subscale to determine its internal consistency. The discriminative ability was assessed by examining the standard deviations and range of responses to each item. Finally, the factor correlation matrix was computed to examine the correlations between the subscales. The results of the validation tests indicated that the questionnaire was a valid and reliable instrument for measuring secondary teachers' attitudes toward teaching integrated STEM.

Measures of teacher background, personal attitudes and school context

Teacher background. Adjoining the attitude questionnaire, survey items were included measuring personal background information including age, gender, experience in teaching (global and specific STEM courses), prior education, non-teaching work experience and attendance of professional development. An overview of the background factors that are taken into account is given in Table 3.

Personal attitudes. Teachers were asked to rate 15 statements about the relevance of mathematics, science and technology in their day-to-day lives on a 5-point Likert scale ranging from totally disagree to totally agree. Exploratory factor analysis produced three factors labeled 'personal relevance of technology', 'personal relevance of mathematics' and 'personal relevance of science'.

School context. This variable was measured by means of fourteen items referring to different elements of school environment. Teachers had to indicate to which extent they felt the different elements were present in their school on a 4-point Likert scale (1= totally absent; 4= more than adequately present). Through exploratory factor analysis (oblique rotation) three categories were defined: 'technical context' (technical material, adjusted classrooms, budget and technical support by experts), 'social context' (content support by colleagues, effective cooperation with other STEM teachers, a clear vision of the management about STEM education, logistical support by management, professional development about content) and 'organizational context' (sufficient teaching hours, small classes (= number of students), ready-made course material).

An overview of all measured variables is given in Figure 3.

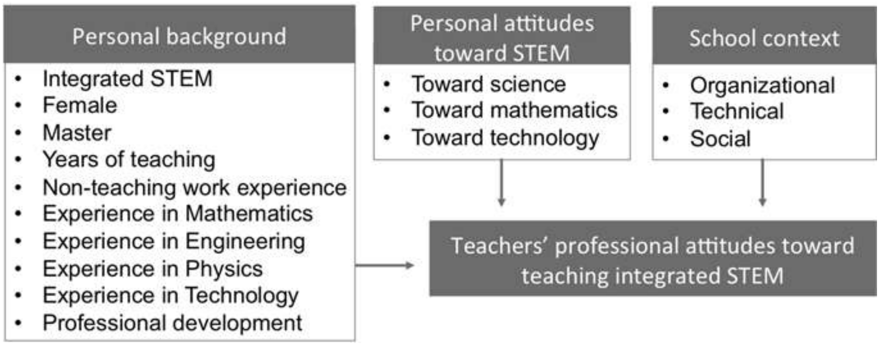


Fig. 3 Overview of all measured variables

Data Analysis

The data was analyzed with SPSS software version 23.0. First, correlation coefficients between all predictor variables and teachers' attitude were calculated. Next, direct multiple regression analysis was used to define the predictor variables most suited to explain the variance in teachers' attitudes. Four different direct regression analyses were conducted: (a) only predictor variables referring to teachers' background; (b) only predictor variables referring to teachers' personal attitudes; (c) only school context predictor variables and (d) a full model.

Results

Correlation

First, the correlation coefficient between all variables was computed (Table 4). When examining the connection between the independent variables, several conclusions can be drawn. For instance, teachers who are involved in teaching an integrated STEM course usually don't have a master's degree, have limited teaching experience but do have experience in teaching engineering. Moreover, a large portion of them actively attend professional development and are positive about both the physical and social context in which their teaching occurs. On the other hand, teachers who do possess a master's degree are less positive about their teaching environment. Moreover, teachers with experience in mathematics often have experience in physics and are mostly women. These teachers rarely have experience in engineering. The bottom line of Table 4 indicates the correlation between the predictor variables and teachers' attitude. Within the teacher background characteristics, four variables are positively correlated with teachers' attitude: experience in integrated STEM, experience in engineering, non-teaching experience and participation in professional development. However, also two variables correlate negatively with teachers' attitude: experience in mathematics and years of teaching experience. The other variables (female, master and experience in physics) do not exert a significant correlation with teachers' attitudes. Within the category of personal attitudes, both the perceived relevance of technology and that of science are found to have a positive correlation with teachers' attitudes. Regarding school context, all three variables are positively linked with attitudes, although the correlation with social context is more pronounced than the other two.

Table 2 Correlation coefficients

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.	17.
1. Int. STEM	1.00																
2. Female	-.150	1.00															
3. Master	**-.254****	**.234****	1.00														
4. Years of teaching	**-. 215***	.025	.007	1.00													
5. Exp Math	-.150	**.451****	.054	-.024	1.00												
6. Exp Physics	.071	**.228****	.098	-.102	**.380****	1.00											
7. Exp Eng	**.214***	**-.385****	-.058	.066	**-.427****	**-.364****	1.00										
8. Exp Tcch	-.009	**-.228****	-.098	.162	-.077	**-.217***	.075	1.00									
9.Non-teaching exp.	.098	-.092	.147	**-.201***	-.165	.148	**.213***	**184***	1.00								
10. Prof. dev.	**.362****	-.049	-.054	-.037	-.080	.018	**.192***	-.018	.145	1.00							
11. Pers. Rel. tech	-.015	.072	**.202***	.000	-.085	.072	.019	**178***	.114	-.032	1.00						
12. Pers. Rel. math	.061	.065	.160	-.068	.128	.151	.090	**211***	.150	.013	**.668****	1.00					
13. Pers. Rel. science	.074	.041	**.197***	-.109	.092	**.256****	-.002	**221***	**.220***	.035	**.745****	**.700***	1.00				
14. Social con	**.252****	-.123	-.169	.098	-.032	.070	.010	.027	.060	.138	-.014	-.025	.043	1.00			
15. Org. con	**.369****	-.143	**-.263****	-.118	.009	.130	.140	-.001	.093	.147	-.056	.019	-.015	**.701****	1.00		
16. Tech. con	**.337****	-.199*	**-.234****	-.176	-.153	-.015	**.203***	.059	.020	.128	-.050	.008	-.036	**.742****	**.844****	1.0	
17. Attitude	**.233****	-.093	.006	**-.248****	**-.235****	.056	**.191***	.005	**.242****	**.270****	**.227****	.144	**.257****	**.302****	**.180***	**.189***	1.0

* Correlation is significant at the 0.05 level (2-tailed).
** Correlation is significant at the 0.01 level (2-tailed).

Regression results

Since effects from one group of variables could disappear when taking into account all groups of variables, four different direct regression analyses were conducted: (a) only predictor variables referring to teachers' personal background ("Background" model); (b) only predictor variables referring to teachers' personal attitudes ("Attitude" model); (c) only school context predictor variables ("Context" model) and (d) taken into account all kinds of predictor variables ("Full" model). The standardized beta weights, *p*-values and amount of explained variances of predictor variables (a), (b), (c) and (d) are presented in Table 5.

Table 5 Standardized beta weights, p-values and explained variances of multiple regression analysis for variables predicting teachers' attitude

	"Background" model		**"Attitude" model**		**"Context" model**		**"Full" model**	
Background characteristics								
	Beta	*p-value*					*Beta*	*p-value*
Integrated STEM	.064	.464					.005	.956
Female	.005	.935					.052	.533
Years of experience								
• 6-10 years	-.019	.847					-.039	.633
• 11-15 years	.148	.137					.009	.108
• 16-20 years	-.141	.083					-.010	.909
• > 20 years	**- .247****	.002					**- .187***	.015
Master	.025	.747					.018	.238
Experience in Physics	.121	.167					.061	.464
Experience in Engineering	-.001	.964					.000	.996
Experience in Mathematics	**-.201***	.013					**-.222****	.004
Experience in Technology	.082	.356					.059	.446
Non-teaching work experience	.149	.073					.090	.256
Professional Development	**.237****	.003					**.199****	.009
Personal relevance								
			Beta	*p-value*			*Beta*	*p-value*
Personal Relevance Technology			.080	.529			.105	.370
Personal Relevance Mathematics			-.69	.557			-.005	.964
Personal Relevance Science			**.257****	.003			**.244****	.004
School context								
					Beta	*p-value*	*Beta*	*p-value*
Social context					**.302****	.000	**.277****	.003
Technical context					-.079	.526	-.129	.256
Organizational context					-.062	.594	-.056	.597
R^2	**.218**		**.073**		**.091**		**.375**	

* Correlation is significant at the 0.05 level (2-tailed).
** Correlation is significant at the 0.01 level (2-tailed).

In the "Background" model, only one variable appears to show a positive relationship with teachers' attitudes, i.e. participation in *professional development*. However, two variables are negatively linked with attitude: *experience in mathematics* and having *more than twenty years teaching experience*. Together, all background characteristics account for 21.8% of the variation in teachers' attitudes. In the "Attitude" model, one variable is positively associated with teachers' attitudes: the *personal relevance* that teachers attribute to *science*. The variables in the "Attitude" model account for 7.3% of the variation in teachers' attitudes toward teaching integrated STEM. In the "Context" model, also one variable is significantly related to teachers' attitudes: *social context*. This variable is positively correlated with attitudes and together with the other school context variables it accounts for 9.1% of the variation in these attitudes.

When taken into account all three types of predictor variables (personal background, personal attitudes and school context), the model accounts for 37.5% of the variance in teachers' attitudes and five significant variables are found. Three of the significant predictor variables are constructively connected to teachers' attitudes toward teaching integrated STEM: *participation in professional development, personal relevance of science* and *social context*. However, for the factors *> 20 years of teaching experience* and *experience in mathematics*, the correlation is in the opposite direction indicating that more years of teaching and experience in mathematics are linked with lower attitudes toward teaching integrated STEM. According to the standardized beta weights social context has the strongest connection with teachers' attitudes toward teaching integrated STEM.

Discussion

To find variables that can explain differences in secondary teachers' professional attitudes toward teaching integrated STEM, three groups of variables were examined: personal background characteristics, personal attitudes toward STEM, and school context factors. Multiple regression analyses were conducted to find significant correlations .

Personal background characteristics were taken into account since they can influence the prevalence of different kinds of experiences (i.e. mastery experiences, vicarious experience, social persuasion and emotional arousal) that can affect a person's attitude (Bandura 1977). Results of the multiple regression analyses show that only one background characteristic is positively correlated with teachers' attitudes toward teaching integrated STEM: *participation in professional development.* Several researchers have already confirmed the positive relationship between participation in professional development and teachers' attitudes. For example, Powell-Moman and Brown-Schild (2011) found significant higher self-efficacy scores for inquiry-based instruction in in-service STEM teachers after completion of a two-year professional development program. Likewise, van Aalderen-Smeets and Van der Molen (2015) showed that involvement in professional development is more effective in changing teachers' attitudes compared to merely being engaged in science teaching.

In addition to the positively correlated factor, two background characteristics also show a negative correlation with teachers' attitudes: *> 20 years of teaching experience* and *experience in mathematics*. For the factor *> 20 years of teaching experience* this is not a surprising result, since prior research (e.g. Klassen & Chiu 2010) about the influence of teaching experience on teachers' self-efficacy already indicated that self-efficacy seems to increase in the early years of teaching while it decreases in the later years of a teacher's career. On the other hand, studies assessing subject-specific differences in teachers' attitudes toward interdisciplinary teaching are still elusive and rare. Salami, Makela and de Miranda (2017) examined the change in attitudes to interdisciplinary teaching of 29 middle and high school teachers who participated in an interdisciplinary teaching and design problem unit that spanned multiple STEM subjects. They reported lower attitude scores for mathematics teachers compared to engineering/technology teachers and science teachers. Moreover, resistance to change was higher in mathematics teachers compared to the other group. While no justification for this observation was given by Salami et al. (2017), a possible explanation might be found in the specific nature of the subject. Mathematics teachers tend to see their subject more axiomatically oriented and less related to empirical findings than science teachers do (Stodolsky & Grossman 1995). Moreover, math teachers use experiments less frequently than science teachers do and they help students less often to understand the world outside school in their lessons (Engeln, Euler & Maass 2013). Therefore, since mathematics teachers are less experienced in conducting experiments and/or working with real world problems in class, which are defining principles of integrated STEM education, they might exhibit lower levels of attitude toward integrated STEM.

In addition to teachers' background characteristics, personal attitudes toward STEM and school context variables were taken into account in the multiple regression analysis. van Aalderen-Smeets and van der Molen (2015) assume that teachers' personal attitudes can positively influence their professional attitudes, although they acknowledge that more research is necessary to define the strength and direction of this relationship. Results of this study show a positive correlation between teachers' attitudes toward teaching integrated STEM and *personal relevance of science*. The non-significance of the other factors (personal relevance of mathematics and of technology) can be explained by the high correlations between the three factors (see Table 4). In a model that already contains *personal relevance of science*, the added value of the other factors is small.

A rationale for including school context variables is given by social cognitive theory (Bandura, 1986), which proposes a bi-directional relationship between environmental factors and a person's attitudes. Results of the current study reveal a positive correlation between teachers' attitudes toward teaching integrated STEM and *social context*. Moreover, according to the standardized beta weights, social context has a stronger connection with teachers' attitudes than the significant background characteristics and personal attitudes. This finding is supported in research literature. DeChenne, Koziol, Needham and Enochs (2015) examined the sources of teaching self-efficacy in 128 graduate teaching assistants in science, technology, engineering, and mathematics. According to their findings, teaching self-efficacy results mostly from a variety of environmental factors rather than through teaching experiences that should have provided mastery experiences. However, unlike the results from this study, they found greater effects of the facilitating environment factor, which included items about resources and allocated time, compared to the peer teaching relationship factor. Some other studies (e.g. Tschannen-Moran & Woolfolk Hoy 2002) also report a stronger connection between teachers' self-efficacy and the availability of resources, compared to the availability of collegial support. However, none of these studies have been conducted within the context of integrated STEM. In more traditional settings, with relatively isolated subjects, it might not be surprising that support from colleagues is valued less than the availability of necessary resources. Findings from this study suggest that this might be different within the context of integrated STEM. Since content from different subjects is combined, forcing teachers out of their comfortzone, peer relations could have a stronger influence on teachers' attitudes than in more traditional settings.

Significance and conclusion

This research aimed at finding variables that can explain differences in secondary teachers' professional attitudes toward teaching integrated STEM. Three variables were found to be positively linked with teachers' attitudes (professional development, personal relevance of science and social context), whereas two variables showed a negative connection (more than 20 years of teaching experience and having experience in mathematics).

Findings of this study are important, since they provide insight into the possible barriers for the successful implementation of integrated STEM education. Results indicate that teachers with more than 20 years of teaching experience report lower attitudes toward teaching integrated STEM compared to their colleagues with less teaching experience. Likewise, teachers with experience in teaching mathematics report lower attitudes than colleagues without experience in teaching mathematics. Since research suggests that teachers' attitudes play a role in the implementation of new instructional practices (Gregoire, 2003, Pintó, 2005; Roehrig, Kruse & Kern, 2007), these two groups of teachers are more likely to experience difficulties when implementing integrated STEM education.

However, the research results are also useful in overcoming these barriers, since they suggest possibilities for improving teachers' attitudes toward teaching integrated STEM, which could ultimately ameliorate the implementation of integrated STEM. The most promising variables in this respect are the factors that are easiest to manipulate, such as professional development and social environment. School administrators who want to facilitate the implementation of integrated STEM should provide sufficient opportunities for collaboration and consultation between different STEM teachers and should stimulate teachers to participate in professional development activities. As explained above, this might be especially crucial when STEM teachers have a lot of teaching experience and/or have experience in teaching mathematics. Interestingly, and in contrast with research results from more traditional settings, social context is more strongly related to teachers' attitudes toward teaching integrated STEM than the availability of (technical) resources. Further research could focus on identifying the specific aspects of both professional development and social context that define the positive correlation with teachers' attitudes.

A final factor that was identified by this study as a potential tool for improving the implementation of integrated STEM is teachers' personal attitude. Teachers who attribute high personal relevance to science report higher professional attitudes toward teaching integrated STEM. Moreover, prior research has showed that these personal attitudes are changeable and can be improved through attitude-focused professional development (van Aalderen-Smeets & Van der Molen 2015). Nonetheless, the strength and direction of the relationship between teachers' personal attitudes and their professional attitudes is not yet clear. Therefore, more research is necessary to decide about the usefulness of personal attitudes when stimulating integrated STEM teaching.

References:

Ajzen, I. (2001). Nature and operation of attitudes. *Annual review of psychology, 52*(1), 27-58.

Andersen, L. B. (2011). Teacher diversity: Do male and female teachers have different self-efficacy and job satisfaction? European Group for Public Administration (EGPA). https://soc.kuleuven.be/io/egpa/HRM/bucharest/ Andersen2011.pdf. Accessed December 2016.

Anderson, R., Greene, M., & Loewen, P. (1988). Relationships among teachers' and students' thinking skills, sense of efficacy, and student achievement. *Alberta Journal of Educational Research*, 34(2), 148-165.

Appleton, K., & Kindt, I. (1999). Why teach primary science? Influences on beginning teachers' practices. *International journal of science education*, *21*(2), 155-168.

Bandura, A. (1977). Self-efficacy: toward a unifying theory of behavioral change. *Psychological review*, *84*(2), 191-215.

Bandura, A. (1986). *Social foundations of thought and action: A social cognitive theory*. Englewood Cliffs, NJ: Prentice-Hall, Inc.

Bandura, A. (1989). Human agency in social cognitive theory. *American psychologist*, *44*(9), 1175-1184.

Bandura, A. (1997). *Self-efficacy: The exercise of control.* New York, NY: Freeman.

Borg, S. (2011). The impact of in-service teacher education on language teachers' beliefs. *System*, *39*(3), 370-380.

Bragow,D., Gragow,K.A., & Smith,E. (1995). Back to the future: Toward curriculum integration. *Middle School Journal*, 27, 39-46.

Brown, J. S., Collins, A., & Duguid, P. (1989). Situated cognition and the culture of learning. *Educational researcher*, *18*(1), 32-42.

Capps, D. K., & Crawford, B. A. (2013). Inquiry-based instruction and teaching about nature of science: Are they happening?. *Journal of Science Teacher Education*, *24*(3), 497-526.

Chen, Z., & Yeung, A. S. (2015). Self-efficacy in Teaching Chinese as a Foreign Language in Australian Schools. *Australian Journal of Teacher Education*, *40*(8), 24-42.

Choi, B. C., & Pak, A. W. (2006). Multidisciplinarity, interdisciplinarity and transdisciplinarity in health research, services, education and policy: 1. Definitions, objectives, and evidence of effectiveness. *Clinical and investigative medicine*, *29*(6), 351-364.

Christensen, R., Knezek, G., & Tyler-Wood, T. (2015). Alignment of hands-on STEM engagement activities with positive STEM dispositions in secondary school students. *Journal of Science Education and Technology*, *24*(6), 898-909.

Collinson, V. (2012). Sources of teachers' values and attitudes. *Teacher Development*, *16*(3), 321-344.

Crook, C., (2016). The Predictive Relationship between Specific Teacher Characteristics and the Perceived Sense of Teacher Self-Efficacy of Non-Native English Speaking Teachers of English as A Foreign Language in Rural Thailand.

Czerniak, C. M., Weber, W. B., Sandmann, A., & Ahern, J. (1999). A literature review of science and mathematics integration. *School Science and Mathematics*, *99*(8), 421-430.

DeChenne, S. E., Koziol, N., Needham, M., & Enochs, L. (2015). Modeling Sources of Teaching Self-Efficacy for Science, Technology, Engineering, and Mathematics Graduate Teaching Assistants. *CBE Life Sciences Education*, *14*(3).

Diggs, V. (2009). Ask--Think--Create: The Process of Inquiry. Knowledge Quest, 37, 30-33.

Donaghue, H. (2003). An instrument to elicit teachers' beliefs and assumptions. *ELT journal*, *57*(4), 344-351.

Drake, S. M., & Burns, R. C. (2004). *Meeting standards through integrated curriculum*. Alexandria, VA: ASCD.

Eagly, A. H., & Chaiken, S. (1993). *The psychology of attitudes*. Fort worth, TX: Harcourt Brace Jovanovich College Publishers.

Eccles, J. S. (1994). Understanding women's educational and occupational choices. *Psychology of women quarterly*, *18*(4), 585-609.

Engeln, K., Euler, M., & Maass, K. (2013). Inquiry-based learning in mathematics and science: a comparative baseline study of teachers' beliefs and practices across 12 European countries. *ZDM*, *45*(6), 823-836.

Finsterwald, M., Wagner, P., Schober, B., Lüftenegger, M., & Spiel, C. (2013). Fostering lifelong learning–Evaluation of a teacher education program for professional teachers. *Teaching and Teacher Education*, *29*, 144-155.

Fox, M. A., & Hackerman, N. (Eds.). (2002). *Evaluating and improving undergraduate teaching in science, technology, engineering, and mathematics*. Washington, D.C.: National Academies Press.

Friend, H. (1985). The effect of science and mathematics integration on selected seventh grade students' attitudes toward and achievement in science. *School Science and Mathematics*, *85*(6), 453-461.

Froyd, J. E. (2008). *White Paper on Promising Practices in Undergraduate STEM Education.* Retrieved from: http://nsf.iupui.edu/media/b706729f-c5c0-438b-a5e4-7c46cc79dfdf/HhFG1Q/CTLContent/FundedProjects/NSF/PDF/2008-Jul-31_Promising_Practices_in_Undergraduate_STEM_Education.pdf

Ginns, I. S., Tulip, D. F., Watters, J. J., & Lucas, K. B. (1995). Changes in preservice elementary teachers' sense of efficacy in teaching science. *School Science and Mathematics*, *95*(8), 394-400.

Goldsmith, C. A., Tran, T. T., & Tran, L. (2014). An educational program for underserved middle school students to encourage pursuit of pharmacy and other health science careers. *American journal of pharmaceutical education*, *78*(9). 1-8.

Gottfried, M. A. (2015). The Influence of Applied STEM Coursetaking on Advanced Mathematics and Science Coursetaking. *The Journal of Educational Research*, *108*(5), 382-399.

Gregoire, M. (2003). Is it a challenge or a threat? A dual-process model of teachers' cognition and appraisal processes during conceptual change. *Educational psychology review*, *15*(2), 147-179.

Hackett, G. (1985). Role of mathematics self-efficacy in the choice of math- related majors of college women and men: A path analysis. *Journal of Counseling Psychology*, *32*(1), 47-56.

Hackett, G., & Betz, N. E. (1981). A self-efficacy approach to the career development of women. *Journal of Vocational Behavior*, *18*(3), 326-339.

Hall, C., Dickerson, J., Batts, D., Kauffmann, P., & Bosse, M. (2011). Are we missing opportunities to encourage interest in STEM fields?. *Journal of Technology Education*, *23*(1), 32-46.

Hennessy, S. & Murphy, P.1999. The Potential for Collaborative Problem Solving in Design and Technology. *International Journal of Technology and Design Education*, *9*(1), 1–36.

Henson, R. K. (2001, January). *Teacher Self-Efficacy: Substantive Implications and Measurement Dilemmas.* Invited keynote at the annual meeting of the Educational Research Exchange, Texas A&M University, Texas.

Herrington, J., & Kervin, L. (2007). Authentic learning supported by technology: Ten suggestions and cases of integration in classrooms. *Educational Media International*, *44*(3), 219-236.

Hinde, E. T. (2005). Revisiting curriculum integration: A fresh look at an old idea. *The Social Studies*, *96*(3), 105-111.

Honey, M., Pearson, G., & Schweingruber, H. (Eds.). (2014). *STEM Integration in K-12 Education: Status, Prospects, and an Agenda for Research*. Washington, DC: National Academies Press.

Hoover-Dempsey, K.V., Bassler, O.C., & Brissie, J.S. (1987). Parent involvement: contribution of teacher efficacy, school socioeconomic status, and other school characteristics. *American Educational Research Journal*, 24(3), 417-435.

Hudson, P., English, L., Dawes, L., King, D., & Baker, S. (2015). Exploring Links between Pedagogical Knowledge Practices and Student Outcomes in STEM Education for Primary Schools. *Australian Journal of Teacher Education, 40*(6), 134-151.

Jarski, R. W., Kulig, K., & Olson, R. E. (1990). Clinical Teaching in Physical Therapy: Student and Teacher Perceptions. *Physical Therapy, 70*(3), 173-178.

Jonassen, D. H. (1999). Designing constructivist learning environments, vol II. In C. M. Reigeluth (Ed.), *Instructional design theories and models: A new paradigm of instructional theory* (pp. 215–240). MahWah: Lawrence Erlbaum Associates, Publishers.

Kafai, Y. B., & Resnick, M. (1996). *Constructionism in practice: Designing, thinking, and learning in a digital world.* Mahwah, NJ: Routledge.

Kagan, D. M. (1992). Implication of research on teacher belief. *Educational psychologist*, *27*(1), 65-90.

Kennedy, S. Y., & Smith, J. B. (2013). The relationship between school collective reflective practice and teacher physiological efficacy sources. *Teaching and Teacher Education*, *29*, 132-143.

Klassen, R. M., & Chiu, M. M. (2010). Effects on teachers' self-efficacy and job satisfaction: Teacher gender, years of experience, and job stress. *Journal of educational Psychology*, *102*(3), 741-756.

Lee, V., Dedrick, R., & Smith, J. (1991). The effect of social organization of schools on teachers' efficacy and satisfaction, *Sociology of Education, 64*(3), 190–208.

Levin, B., & He, Y. (2008). Investigating the content and sources of teacher candidates' personal practical theories (PPTs). *Journal of Teacher Education*, *59*(1), 55-68.

Lortie, D. C., & Clement, D. (1975). *Schoolteacher: A sociological study*. Chicago, IL: University of Chicago Press.

Lumpe, A. T., Haney, J. J., & Czerniak, C. M. (2000). Assessing teachers' beliefs about their science teaching context. *Journal of research in science teaching*, *37*(3), 275-292.

Maltese, A. V., & Tai, R. H. (2011). Pipeline persistence: Examining the association of educational experiences with earned degrees in STEM among US students. *Science Education*, *95*(5), 877-907.

Mansour, N. (2009). Science Teachers' Beliefs and Practices: Issues, Implications and Research Agenda. *International Journal of Environmental and Science Education*, *4*(1), 25-48.

McComas, W. R, & Wang, H. A. (1998). Blended science: The rewards and challenges of integrating the science disciplines for instruction. School Science and Mathematics, 98(6), 340-348.

McComas, W.R (1993). STS education and the affective domain. In R. E. Yager (Ed.), What research says to the science teacher, 7: The science, technology, and society movement (pp.161-168). Washington, DC: National Science Teachers Association.

Mellati, M., & Khademi, M. (2015). The Relationships among Sources of Teacher Pedagogical Beliefs, Teaching Experiences, and Student Outcomes. *International Journal of Applied Linguistics and English Literature*, *4*(2), 177-184.

Menmuir, J., & Adams, K. (1997). Young children's inquiry learning in mathematics. Early Years, 17(2), 34-39.

Mizell, H. (2008, July). *NSDC's definition of professional development: The second dimension.* Lecture presented at National Staff Development Council's Summer Conference*,* Orlando, FL.

Moore, T. J., & Smith, K. A. (2014). Advancing the State of the Art of STEM Integration. *Journal of STEM Education: Innovations and Research*, *15*(1), 5-10.

Nespor, J. (1987). The role of beliefs in the practice of teaching. *Journal of curriculum studies*, *19*(4), 317-328.

Nugent, G., Barker, B., Grandgenett, N., & Adamchuk, V. I. (2010). Impact of robotics and geospatial technology interventions on youth STEM learning and attitudes. *Journal of Research on Technology in Education*, *42*(4), 391-408.

Pettus, A. M. (1994, October). *Models for Curriculum Integration in High School.* Paper presented at the Annual Meeting of the Southeastern Regional Asociation of Teacher Educators, Virginia.

Pinnell, M., Rowly, J., Preiss, S., Franco, S., Blust, R., & Beach, R. (2013). Bridging the gap between engineering design and PK-12 curriculum development through use of the STEM education quality framework. *Journal of STEM Education: Innovations and Research*, *14*(4), 28-35. Retrieved from: ProQuest Central.

Pintó, R. (2005). Introducing curriculum innovations in science: Identifying teachers' transformations and the design of related teacher education. *Science Education*, *89*(1), 1-12.

Polat, N. (2010). A comparative analysis of pre-and in-service teacher beliefs about readiness and self-competency: Revisiting teacher education for ELLs. *System*, *38*(2), 228-244.

Powell-Moman, A. D., & Brown-Schild, V. B. (2011). The influence of a two-year professional development institute on teacher self-efficacy and use of inquiry-based instruction. *Science Educator*, *20*(2), 47-53. Retrieved from: EPSCO.

Powell-Moman, A. D., & Brown-Schild, V. B. (2011). The influence of a two-year professional development institute on teacher self-efficacy and use of inquiry-based instruction. *Science Educator*, *20*(2), 47.

Pratkanis, A. R., Breckler, S. J., & Greenwald, A. G. (2014). *Attitude structure and function*. Hillsdale, NJ: Erlbaum.

Ramey□Gassert, L., Shroyer, M. G., & Staver, J. R. (1996). A qualitative study of factors influencing science teaching self□efficacy of elementary level teachers. *Science Education*, *80*(3), 283-315.

Raudenbush, S.W., Rowan, B. & Cheong, Y.F. (1992). Contextual Effects on the Self-Perceived Efficacy of High School Teachers. *Sociology of Education*, *65*(2), 150-167.

Rieber, L. P. (1993). A pragmatic view of instructional technology. In K. Tobin (Ed.), *The practice of constructivism in science education* (pp. 193-212). Washington, DC: AAAS Press.

Roebuck, K. I., & Warden, M. A. (1998). Searching for the Center on the Mathematics□Science Continuum. *School Science and Mathematics*, *98*(6), 328-333.

Roehrig, G. H., Kruse, R. A., & Kern, A. (2007). Teacher and school characteristics and their influence on curriculum implementation. *Journal of Research in Science Teaching*, *44*(7), 883-907.

Ross, J., & Bruce, C. (2007). Professional development effects on teacher efficacy: Results of randomized field trial. *The Journal of Educational Research*, *101*(1), 50-60.

Sade, D., & Coll, R. (2003). Technology and Technology Education: Views of some Solomon Island primary teachers and curriculum development officers. International Journal of Science and Mathematics Education, 1(1), 87-114.

Savas, B., Senemoglu, N., & Kocabas, A. (2012). The effects of integrated unit and constructivist based teaching learning process on fourth grades students' learning levels, attitudes towards learning, academic self-confident. *Procedia-Social and Behavioral Sciences*, *46*, 2811-2815.

Stodolsky, S. S., & Grossman, P. L. (1995). The impact of subject matter on curricular activity: An analysis of five academic subjects. *American Educational Research Journal, 32*(2), 227–249.

Streveler, R. A., Smith, K. A., & Pilotte, M. (2012). Aligning course content, assessment, and delivery: Creating a context for outcome-based education. In *Outcome-based science, technology, engineering, and mathematics education: Innovative practices* (pp. 1-26). IGI Global.

Tschannen-Moran, M., & Woolfolk Hoy, A. (2002, April). The influence of resources and support on teachers' efficacy beliefs. In *annual meeting of the American Educational Research Association, New Orleans, LA*.

Turnbull, W. (2002). The place of authenticity in technology in the New Zealand curriculum. International Journal of Technology and Design Education, 12(1), 23-40.

Tweed, S. R. (2013). *Technology implementation: teacher age, experience, self-efficacy, and professional development as related to classroom technology integration.*(Unpublished doctoral dissertation). East Tennessee State University, Johnson City.

van Aalderen-Smeets, S. I., Walma van der Molen, J., & Asma, L. J. (2012). Primary teachers' attitudes toward science: A new theoretical framework. *Science education, 96*(1), 158-182.

van Aalderen□Smeets, S. I., & Walma van der Molen, J. H. (2015). Improving primary teachers' attitudes toward science by attitude□focused professional development. *Journal of research in science teaching*, *52*(5), 710-734.

Vars, G. F. (2001). Can curriculum integration survive in an era of high-stakes testing?. *Middle School Journal*, *33*(2), 7-17.

Wang, X. (2013a). Modeling entrance into STEM fields of study among students beginning at community colleges and four-year institutions. *Research in Higher Education*, *54*(6), 664-692.

Wang, X. (2013b). Why students choose STEM majors motivation, high school learning, and postsecondary context of support. *American Educational Research Journal*, *50*(5), 1081-1121.

Webb, D. L. (2015). *Engineering Professional Development: Elementary Teachers' Self-efficacy and Sources of Self-efficacy*. (Unpublished doctoral dissertation). Portland State University, Portland.

Weilbacher, G. (2001). Is curriculum integration an endangered species?. *Middle School Journal*, *33*(2), 18-27.

Zeichner, K. M., & Tabachnick, B. R. (1981). Are the Effects of University Teacher Education. *Journal of teacher education*, *32*(3), 7-11.

Zemelman, S., Daniels, H., & Hyde, A. (2005). Best practice in mathematics. In S. Zemelman, H. Daniels, & A. Hyde (Eds.), *Best practice: Today's standards for teaching and learning in America's schools,* (pp. 106-118*).* Portsmouth, NH: Heinemann.

(