Int J Technol Des Educ (2017) 27:63–88
DOI 10.1007/s10798-015-9341-0

Assessing changes in teachers' attitudes toward interdisciplinary STEM teaching

Mubarak K. Al Salami[1] · Carole J. Makela[1] · Michael A. de Miranda[1,2]

Accepted: 23 October 2015 / Published online: 3 November 2015

Abstract Integrating engineering and technology concepts into K-12 science and math curricula through engineering design project-based learning has been found to increase students' interest in science, technology, engineering, and mathematics (STEM), however preparing teachers to shift to interdisciplinary teaching remains a significant challenge. Primarily teachers need to develop both skills and attitudes toward interdisciplinary teaching. In doing so, professional development (PD) is considered a key component in helping teachers through this transformation process. In an educational environment of accountability, measuring the effects of PD programs on teacher behaviors and capacity is essential but often elusive. The current study describes the change in attitudes to interdisciplinary teaching of 29 self-selected middle and high school teachers who participated a PD workshop and in delivering a 12–15 week interdisciplinary teaching and design problem unit that spanned multiple STEM subjects. This quasi-experimental pilot study implemented a single group pretest–posttest design using survey methods to collect data from the participants at two intervals; at the time of the PD workshop and at the completion of the teaching unit that emphasized a long-term engineering design problem. The goals of this research are to (1) assess the changes in attitudes to interdisciplinary teaching, attitudes to teamwork, teaching satisfaction, and resistance to change, (2) explore relationships among these changes, (3) and describe the variation in these changes across teachers' gender, school level, discipline taught, and education level.

This program is based upon collaborative work supported by a National Science Foundation Grant No. 0841259; Colorado State University, Thomas W. Chen, Principal Investigator, Michael A. de Miranda and Stuart Tobet, Co-Principal Investigators. Any opinions, findings, conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.

✉ Mubarak K. Al Salami
alsalamihome@hotmail.com

[1] School of Education, Colorado State University, Fort Collins, CO 80523, USA

[2] Department of Electrical and Computer Engineering, Colorado State University, Fort Collins, CO 80523, USA

Keywords Interdisciplinary STEM teaching · Teacher professional development · Engineering design · Teacher attitudes · K-12 STEM education

Advances in science, technology, engineering, and mathematics (STEM) are projected to be the driving force of the future economic and overall well-being not only for advanced economies like the United States but also for growing economies worldwide. While the demand for STEM professionals in the U.S. is expected to increase by 17 % between 2008 and 2018 (Langdon et al. 2011), there is a shortage of well-educated STEM workers to support these growing economies (Rockland et al. 2010). Adding to the shortage of highly trained STEM workers is a high percentage of students who are not interested in pursuing studies in STEM related fields, particularly in engineering (Rockland et al. 2010). This may be attributed to how students have experienced learning STEM subjects in their formative years of compulsory education (Rockland et al. 2010). For these reasons, many recent educational initiatives have been introduced into K-12 education to increase students' interest in STEM by integrating engineering and technology concepts into science and mathematics curricula (Brown et al. 2011). One approach that holds promise is the use of engineering design that engages students in solving authentic problems while collaborating with others to build, design, or conceptualize real solutions (Laboy-Rush 2011). Implementing engineering design based units into the STEM curriculum is an example of project-based learning that was found to increase students' interest in STEM learning (Hernandez et al. 2013).

However, the success of such initiatives depends mainly on "teacher attitudes toward several shifts in teaching practices" (Laboy-Rush 2011, p. 6). This determines the level of their commitment to infuse engineering principles and design into daily classroom practices (Rockland et al. 2010). To enhance students' perceptions of and interests in STEM, teachers need to develop positive attitudes toward teaching beyond their disciplines, positive attitudes toward collaboration with other teachers, and willingness to change current instructional strategies. Teacher professional development (PD) is a capacity building component that can support teachers in implementing changes to achieve desired student learning outcomes (Custer and Daugherty 2009). However, at this time there is little data to determine if the involvement of mathematics, science, technology, and engineering teachers in the implementation of engineering design curriculum changes their perceptions of an interdisciplinary STEM curriculum. In addition, there is a need for studies that examine the characteristics of teachers who contribute to the success of the implementation of interdisciplinary STEM curriculum. Therefore, this study aims to assess teachers' conceptual changes toward interdisciplinary STEM teaching through their participation in the implementation of a unit with instructional strategies that emphasis an engineering design approach.

In this investigation, four constructs—attitudes toward teamwork, attitudes toward interdisciplinary teaching, teaching satisfaction, and teacher resistance to change—were examined and data were collected from 42 middle school and high school teachers. Data were collected at two intervals; at the time of the PD workshop and at the completion of teaching a 12–15 weeks unit that emphasized engineering design based instruction.

Background

The need to infuse engineering and technology into K-12 curriculum and forms of target outcomes have been addressed by many national documents such as Benchmarks for Science Literacy, the National Education Standards, and the Standards for Technological

Literacy (as cited in Yaşar et al. 2006, p. 206). These documents state clearly that students should "be able to understand and/or apply the engineering design process, recognize the design constraints, and trade-offs of each design alternative" (Yaşar et al. 2006, p. 206). In addition, the Science Framework for K-12 education in the new Next Generation Science Standards describes eight practices of science and engineering that are essential for all students to learn (NGSS Lead States 2013, pp. 8–9). They include:

1. Asking questions (for science) and defining problems (for engineering)
2. Developing and using models
3. Planning and carrying out investigations
4. Analyzing and interpreting data
5. Using mathematics and computational thinking
6. Constructing explanations (for science) and designing solutions (for engineering)
7. Engaging in argument from evidence
8. Obtaining, evaluating, and communicating information

Despite the emphasis on the importance of engineering design within national level standards and curriculum guides, a survey study of 98 science teachers (non-random sample) in Arizona found that all teachers were unfamiliar with engineering design and lacked confidence about their ability to teach an engineering design process (Yaşar et al. 2006). While significant efforts have been made to develop curricula that foster STEM learning, research on the type of support (e.g., PD) teachers need to implement new STEM curricula that includes engineering and scientific practice is limited (Penuel et al. 2007). In response, the U.S. Department of Education and the National Science Foundation (NSF) have funded studies that aim to investigate how to maximize the impact of PD on the quality of instruction and students' performance in the STEM fields (Penuel et al. 2007). There are increasing attempts to understand the connection between the design and delivery of PD and the impact on teaching and students' learning (Penuel et al. 2007).

Factors impacting teacher professional development effectiveness

Many studies examined the factors that make PD effective. These factors can be classified into three categories–factors related to the design of the PD; factors related to the context; and factors related to the characteristics of participants. Avalos (2011) reviewed 111 publications in *Teaching and Teacher Education* over 10 years (2000–2010) on teachers' PD and identified three approaches or designs that have been used to facilitate learning and stimulate teachers to alter their instructional practices. They are school-university partnerships, which characterize this study, teacher co-learning, and workplace learning. Based on this review, Avalos classified the factors that affect the success of teachers' professional learning into three major types: contextual factors, structural features of the program, and process features. Examples of the contextual factors may include pressure from policy, community, and media (McIntyre and Kyle 2006), the school environment and support (Borko et al. 2002; Coskie and Place 2008; Henning 2000; Ingvarson et al. 2005; Park et al. 2007), the impact of accountability system and high-stakes assessment (Boardman and Woodruff 2004; Cochrane-Smith 2001; Delandshere and Arens 2001; Sandholtz 2002; Skerrett 2010); and how school culture stimulates or inhabits teachers' professional growth and commitment to learning goals (Jurasaite-Harbison and Rex 2010; King 2002; Knight 2002; Melville and Wallace 2007; Muijs and Harris 2006; Sato and Kleinsasser 2004; Snow-Gerono 2008). The structural features include the design of PD (e.g., Bartholomew and Sandholtz 2009) and its duration (e.g., Ingvarson et al. 2005). The process features include tools that facilitate learning such as reflection processes as an instrument for teacher change. Example of reflective processes include narrative accounts, self-assessment, and portfolios (Breault and Breault 2010; Runhaar et al. 2010). Each of these studies examined the external factors that affect teachers' professional growth.

Thus, there is a need for a study that examines the influences of the characteristics of participants themselves on the success of their professional learning. For example, Avalos (2011) described professional learning as a complex process in which teachers must be cognitively and emotionally involved and highlighted the need for examining teachers' beliefs, convictions, and willingness. Yaşar et al. (2006) asserted the importance of assessing teachers' perceptions and preferences concerning engineering design before designing a curriculum to prepare pre-service and in-service teachers to teach it. Since the aim of effective PD is to increase teachers' interest in interdisciplinary teaching, it is important to assess their perceptions after they have taught a unit based on interdisciplinary content.

Interdisciplinary STEM content constitutes a key feature in this investigation's instructional approach and suggests that exposing teachers to a interdisciplinary STEM 'ideology' would promote the implementation of various teaching strategies and teamwork (Tal et al. 2001). This means that a certain set of skills and knowledge to begin implementing interdisciplinary curriculum is required. For example, teachers are expected to meet in groups to discuss strategies and content and to develop instructional plans (Rockland et al. 2010). Rockland et al. (2010) identified teamwork atmosphere among other factors that should be included in any successful PD program. Custer and Daugherty (2009) considered teamwork among the key elements of effective STEM PD, consistent with findings from the literature.

Another aspect of teacher behavior critical for interdisciplinary curriculum acceptance is low resistance to change. Introduction of an educational reform often involves new roles for teachers (Jaros 2010). Smith (2005) asserted "Because change brings uncertainty, manifestations of change resistance are a natural and expected part of any process of organizational change" (p. 520). Different teachers may react differently to change. While some teachers might welcome change, others might resist. The level of resistance to change related to an educational reform helps determine teachers' commitment to change initiatives. Teachers who are committed to change put forth more, and better, effort toward implementing it (Jaros 2010).

Another critical aspect that s teachers' performance is their satisfaction with teaching (Demirtas 2010). Shann (1998) mentioned "Teacher satisfaction is a pivotal link in the chain of education reform. Teacher satisfaction influences job performance, attrition, and ultimately, student performance" (p. 68). Thus, identification of teachers' job satisfaction level is important. Teachers with low satisfaction may demonstrate low commitment to improve their instructional pedagogy and this may limit their commitment to change needed for interdisciplinary teaching.

Conceptual framework

To assess the changes in teachers' attitudes after their participation in the PD and teaching experience, the study was informed by the conceptual model of teacher change proposed by Guskey (2002a, b) shown in Fig. 1.

Teachers change their beliefs and attitudes toward a new teaching approach or toward a new curriculum after they see it work. Guskey argued;

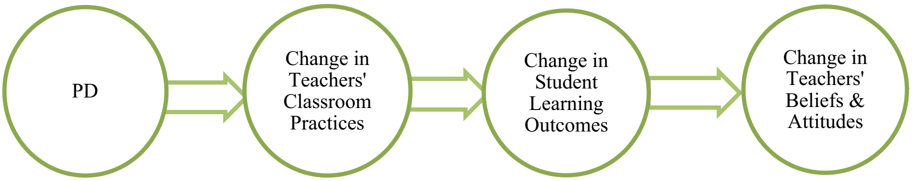

Fig. 1 A model of teacher change

> …significant change in teachers' attitudes and beliefs occurs primarily after they gain evidence of improvements in student learning. These improvements typically result from changes teacher have made in their classroom practices-a new instructional approach, the use of new materials or curricula, or simply a modification in teaching procedures or classroom format. The crucial point is that it is not the PD per se, but the experience of successful implementation that changes teachers' attitudes and beliefs (p. 383).

According to this model, the change in teachers' attitudes could be used as evidence of the influence on teaching and learning that teachers have experienced. As the aim of this investigation was to improve teachers' attitudes to interdisciplinary teaching, measuring change between the pretest and the posttest may be used as an indicator of change in attitudes to interdisciplinary teaching. In addition, implementing an interdisciplinary unit requires collaborations among teachers from different disciplines. When teachers work as a part of an interdisciplinary team for a relatively long period, changes in their attitudes to teamwork are likely to occur (Tal et al. 2001). Measuring the change in teachers' attitudes to teamwork may be used as another indicator of the impact of the PD on teachers. However, research indicates that changes in classroom practices are determined by teachers' commitment to the initiatives undertaken and the processes of implementation, which are influenced by the levels of their teaching satisfaction (Ma and MacMillan 1999) and resistance to change (Smith 2004, 2005). As a result, the conceptual model presented in Fig. 2 was developed to evaluate the change in teachers' attitudes to interdisciplinary teaching.

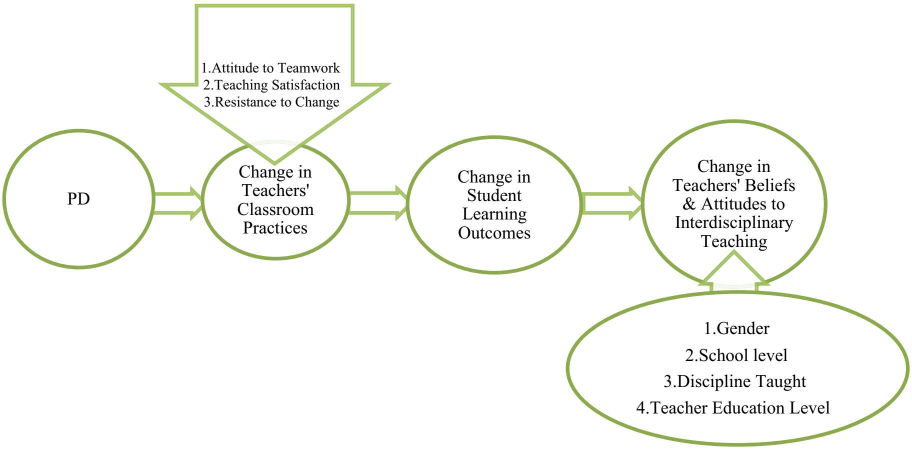

Fig. 2 Conceptual model of teacher change through an in-service PD experience

Using the model in Fig. 2 as a conceptual guide to framing this investigation, attitudes to interdisciplinary teaching, as the dependent variable, is affected by attitudes toward teamwork, teaching satisfaction, and resistance to change. In addition, it is worth exploring if change in attitudes to interdisciplinary teaching differs across teachers' gender, school level, education level, and discipline taught. This model, however, does not account for the influence of other uncontrolled variables such as those related to individual self-efficacy or context-related-variables like school and administrative support.

The inter-relationships among variables included in this model are supported by a number of studies. For example, the empirical study conducted by Reyes and Shin (1995) found a causal relationship between job satisfaction and teacher commitment from longitudinal career data and commitment and satisfaction with a sample of 854 teachers. From surveying 200 middle school teachers and interviewing 58 of them, Shann (1998) identified significant positive correlations between students' achievement and each or both teacher satisfaction and teacher–teacher relationship. Tal et al. (2001), from an analysis of qualitative data collected along with a pre and post survey from 28 teachers who participated in a 2-year PD program, found a more collaborative pattern of teamwork emerged among participants. Although teachers reported that teamwork was time consuming, they considered it a significant contributor to the change in their teaching practices (Tal et al. 2001).

The influence of resistance to change on curricular implementation was highlighted by Goodlad (1983) asserting

> In practice, however, teachers cling to conventional teaching practices because of the circumstances of their classrooms, (and) the models with which they are most familiar…. teachers often respond eagerly to alternative methods of teaching that relate to many of their deepest professional values when they are giving support, encouragement, and protection (p. 553).

Because professional practice in teaching and the length of time in service to develop and refine practices mentioned by Goodlad, researchers might expect differences between less and more experienced teachers. Therefore this informs the possibility that length of time as a professional educator may impact teachers' resistance to change or implementation of a curricular innovation.

Research context

The project in which this investigation was imbedded focused on developing an innovative program for training a new generation of scientists in biomedical science and engineering who are multidisciplinary in their training, better equipped for multilevel communication across school level and disciplines, and prepared to take leadership roles for scientific inquiry and progress as we move through the 21st century (Chen et al. 2009). The intent of the project was to improve the interdisciplinary nature of STEM research and education along the K-12 continuum. Six doctoral students in chemistry, biology, and electrical and computer engineering were employed as research fellows to provide technical and content support to participating teachers. The fellows conducted classroom visits, responded to teachers' questions, and helped in the development of new STEM content. Therefore, the involvement of the research fellows with STEM teachers was focused on translating biomedical science and engineering research into new content for the K-12 STEM classroom. Throughout the fall 2013, K-12 students and their teachers were engaged in an engineering design process unit similar to that of the university partnering research fellows and project faculty.

The PD experience for teachers emphasized the intersection of engineering, mathematics, and biology in a biomedical engineering theme. The 5-day intensive summer 2013 PD experience brought 42 high school and middle school science (biology, chemistry, physics), math, and engineering and technology education teacher teams together to learn how to implement an innovative approach to a biomedical engineering design project. Workshop elements included instruction on how to "blueprint" curriculum, using students' engineering and scientific notebooks for assessment, planning, designing, and implementing and aligning common core standards-based on a biomedical engineering design project. All teacher participants completed the 5-day workshop and were provided with all necessary lessons and instructional resources to deliver the fully integrated biomedical engineering unit to their students in fall 2013. Details about project's participants, workshops, and activities are available at http://csu-gk12.engr.colostate.edu/jrfellows/.

Intervention learning cycle

Figure 3 presents the learning cycle of the PD experience that teachers had through their participation in the PD workshop and implementation process.

Figure 3 shows that the cycle began with the summer 1 week workshop. Teachers went home with all materials required for the implementation process. Teachers taught the interdisciplinary unit to students in their classrooms for 12–15 weeks throughout fall 2013. During this period, teachers were expected to engage in discussions with teachers from other disciplines and with the research fellows who were assigned to support them as content experts. Throughout the process of teacher-fellow collaboration, students in the classrooms were learning the core concepts related to the biomedical engineering content or prerequisite knowledge while they were engaging in engineering design. The roles of teachers were to get students to work in teams and help them integrate knowledge from the STEM subjects.

Research focus

The purpose of this study was threefold; first, to describe changes in in-service teachers' perceptions of interdisciplinary teaching, attitudes toward teamwork, teaching satisfaction,

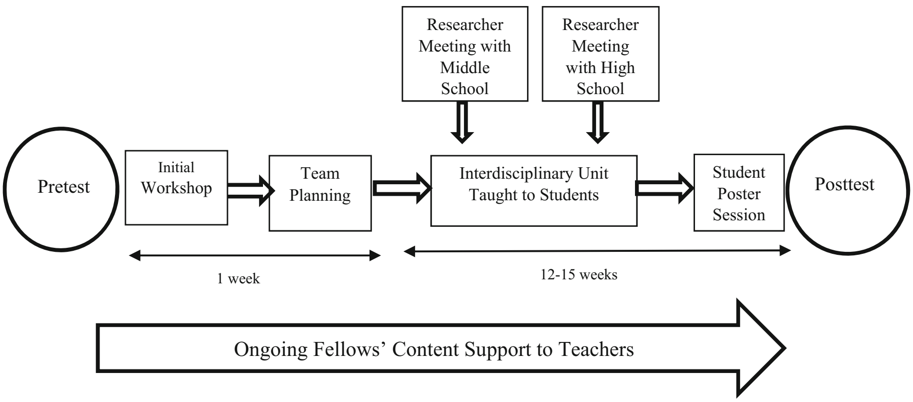

Fig. 3 The learning cycle of the PD experienced by 42 teachers

and resistance to change after being involved in a PD experience, which included teaching a unit that emphasized engineering design; second, to explore relationship among changes; and third, to describe the variations in these changes across teachers' gender, school level, discipline taught, and education level.

Methodology

This study was designed as a quasi-experimental with pretest–posttest single group design (Gliner and Morgan 2000) using the survey method. Shaha et al. (2004) asserted, "Pre-test and posttest designs add the capability to assess change or improvement (immediate and continuous), as well as the ability to adjust for preexisting differences. Improvement, or change from pre-test to posttest occasions, is increasingly being seen as a primary and fundamental measure of program success" (p. 4). The sources of data were a survey instrument administered to 42 teachers who participated in the PD workshop and in teaching a unit using approaches that emphasized engineering design. In addition to demographic questions, the survey included items that measured five scales; teachers' attitudes toward teamwork, teachers' attitudes toward interdisciplinary teaching, teachers' resistance to change, teachers' job satisfaction, and teachers' prior experiences with interdisciplinary teaching or team teaching. The same survey was administered two times, at the time of the PD workshop and at the completion of teaching the unit that extended from 12 to 15 weeks. Time to complete the unit varied across schools due to school calendars and school day scheduling.

Qualitative methodology

To obtain in-depth insights of the teachers, the researchers collected qualitative data from two 1-h meetings with all teacher participants, one with middle school teachers (n = 17) and one with high school teachers (n = 12). The researchers asked teachers from each school to form one group and to answer two open-ended questions: "What are the successes with the implementation process?", and "What are the challenges/uncertainties with the implementation process?" Each group wrote notes about successes and challenges or issues of concerns and the researchers collected groups' notes at the end of each meeting. Groups' discussions and the notes documented and analyzed for identification of themes.

Research questions

This study was designed to examine and test the following questions:

1. Are there measured changes in Attitudes toward Interdisciplinary Teaching, Attitude toward Teamwork, Teaching Satisfaction, and Resistance to Change between the pretest and the posttest across each scale?
2. Does any observable change in Attitudes toward Interdisciplinary Teaching, Attitudes toward Teamwork, Teaching Satisfaction, and Resistance to Change vary across teachers' gender, school level, education level, and discipline taught in fall 2013?
3. Are there associations between the change in Attitudes toward Interdisciplinary Teaching and the changes in Attitudes toward Teamwork, Teaching Satisfaction, and Resistance to Change?

Qualitative open-ended questions:

1. What are the successes with the implementation process?
2. What are the challenges/uncertainties with the implementation process?

Instrumentation

Perceptions toward interdisciplinary teaching

Bayer (2009) defined interdisciplinary teaching as

> …applying methods and language from more than one discipline to examine a theme, issue, question, problem, topic, or experience. Interdisciplinary curriculum creates connections between traditionally discrete disciplines such as mathematics, the sciences, social studies, or history, and English language arts (p. 12).

The researchers could not identify an existing scale that specifically addressed teachers' perceptions of interdisciplinary teaching and teamwork. However, there was one instrument on the perceptions of interdisciplinary curriculum, which included 3 items that assessed prior experiences with interdisciplinary teaching and 14 items assessing attitudes to interdisciplinary teaching. The instrument designed by John A. Bayer, is based on a model developed by Daniel J. Rossiter (as cited in Bayer 2009). Although the instrument lacked documented validity and reliability statistics, Cronbach's alpha coefficients were computed. All items used a five-point Likert scale measuring agreement [ratings from *strongly disagree* (1) to *strongly agree* (5)]. The computed alphas for attitude to interdisciplinary teaching (14 items) was estimated as $\alpha = 0.84$ for the pre-test ($n = 29$) and 0.85 for the post-test ($n = 29$).

Attitude toward teamwork

Teamwork can be defined as a group of people working interdependently to accomplish a task (Kraut and Korman 1999). Attitudes to teamwork were assessed using the aforementioned instrument (Bayer 2009). The instrument includes three items that assess attitudes toward teamwork (ratings from *strongly disagree* to *strongly agree*). The calculated alphas were .72 ($n = 29$) and .61 ($n = 29$) for the pretest and posttest, respectively.

Teaching satisfaction

Ho and Au (2006) defined teaching satisfaction as "a function of perceived relation between what one wants from one's job and what one perceives teaching as offering or entailing" (p. 172). The study implemented a 4-item version of the Teaching Satisfaction Scale (TSS) developed by Ho and Au (2006). The scale has been extensively used as an indicator of teachers' job satisfaction. The Cronbach internal consistency (alpha) coefficient for the five items version reported by Ho and Au was .77 from a sample of 202 primary and secondary school teachers. The TSS 2-weeks test–retest reliability coefficient was .76. The corrected item-total correlations for the five TSS items were .56, .56, .63, .66, and .34. However, confirmatory factor analysis conducted by Demirtas (2010) suggested the use of the four items version. This study used the 4-items scale. All items used a five-point Likert agreement scale (ratings from *strongly disagree* to *strongly agree*).

Resistance to change

Resistance to change was measured by the 4-item scale developed by Oreg (2003). The Cronbach internal consistency (alpha) coefficient for the full scale as reported by Oreg was .87. The scale has been widely used to predict reactions to specific change and to assess resistance to change. All items in the scale used a five-point Likert agreement scale (ratings from *strongly disagree* to *strongly agree*).

Scale descriptive statistics and reliability coefficients

For the purpose of this study, Cronbach's alphas were calculated for all four measures. Table 1 shows means, standard deviations, Cronbach's alphas, and the possible score ranges for attitudes toward interdisciplinary teaching, attitudes toward teamwork, resistance to change, and teaching satisfaction.

Sample and procedure

The sample in this study is comprised of middle school and high school teachers who were teaching STEM disciplines in the Cherry Creek School District located in the State of Colorado, USA. Data were collected during 2013–2014 academic school year. The sample consisted of 42 self-selected teacher participants from 14 schools; 24 participants from 10 middle schools, and 18 participants from 4 high schools. See Appendix 2 for descriptions and characteristics of students of the schools.

The researchers distributed the pretest survey on the first day of the PD workshop site at the beginning of the session. The posttest survey was emailed to all participants at the end of fall 2013. Thirty-six teachers returned the survey in the pretest and 35 in the posttest using three reminders. Twenty-nine teachers completed both the pretest and the posttest and were matched in the analysis. One-third (31 %) of the sample teachers had <5 years of experience in teaching the same discipline taught in fall 2013, 38 % had between 5 and 15 years, and 31 % had more than 15 years of experience. About 76 % had a graduate degree. The male:female ratio was 45 %:55 %. Disciplines of what they taught in fall 2013 were 55 % science (biology, chemistry, physics), 24 % technology or engineering, and 21 % math. Table 2 shows the teachers' demographics across gender, school level, education level, and discipline taught in fall 2013.

Table 1 Possible score ranges, means, standard deviations, and Cronbach's alphas for attitudes toward interdisciplinary teaching, attitudes toward teamwork, resistance to change, and teaching satisfaction (N = 29)

Scale/construct	Possible score range	Pretest			Posttest		
		M	SD	Cronbach's alpha (α)	M	SD	Cronbach's alpha (α)
Attitude toward interdisciplinary	14–70	56.93	7.19	.84	55.97	6.88	.85
Attitude toward teamwork	3–15	12.52	2.05	.72	12.41	1.99	.61
Resistance to change	17–85	42.34	8.42	.83	43.83	5.73	.66
Teaching satisfaction	4–20	15.03	3.19	.82	15.00	3.51	.80

Table 2 Number of participants, means, and standard deviations for number of years teaching the same discipline taught in 2013 across school level, gender, education level, and discipline taught (N = 29)

Variable	Number of participants	Years teaching the same discipline			
		M	SD	Median	Range
School level					
Middle school	17	11.33	7.29	8.00	2–25
High school	12	11.35	10.37	11.00	2–36
Gender					
Male	13	13.92	10.09	9.00	2–36
Female	16	9.25	7.87	16.00	2–32
Teacher education level					
BA/BS	7	7.86	5.93	9.00	2–18
MA/MS	22	12.45	9.72	11.50	2–36
Discipline taught					
Science	16	13.56	10.41	11.00	2–36
Tech./Eng.	7	9.43	7.39	8.00	2–18
Math	6	7.67	5.79	7.00	2–16

Analytical approach

The following analyses were conducted to answer the research questions. The paired-samples *t* tests and Wilcoxon signed ranks tests examined if there is any significant overall changes in each of the four constructs as addressed by the first research question. This decision was based on the outcomes of checking related assumptions (Field 2009). According to Field (2009), paired-samples *t* tests are used to identify differences in means between two experimental conditions when the same participants took part in both conditions. However, Wilcoxon signed ranks tests are performed if the dependent variables are not normally distributed (Field 2009). The second question was investigated by computing means, standard deviations, and 95 % confidence intervals (CI) for each of the four constructs across the demographic variables. A confidence interval is an evidence-based approach for constructing an interval around the point estimate (Gliner and Morgan 2000). "Confidence intervals discourage making decisions based on a single study. Instead, it encourages replication of studies as its basis" (p. 249). The associations between the change in attitudes to interdisciplinary teaching and the changes in the other three measures, in the third question, were assessed by conducting Pearson's correlations to describe the relationships between two continuous variables when both variables are normally distributed (Gliner and Morgan 2000). The findings from the two qualitative questions were analyzed using school level (middle and high school) as a unit of analysis to identify themes and pattern (Creswell 2012). Data were coded manually using inductive coding technique as Miles and Huberman (1994) suggested "by waiting for the field notes to suggest more empirically driven labels" (p. 65). These labels were grouped into a smaller number of themes using a pattern coding analytical technique (Miles and Huberman 1994).

Results

Quantitative results

All analyses were completed using SPSS version 22. Prior to the main analysis, exploratory data analysis was conducted to check for missing values or entry errors. The prior experiences of participants with interdisciplinary teaching or teamwork (years) were calculated across teachers' gender, school level, education level, and discipline taught. Table 3 shows means, standard deviations, and the 95 % CIs for prior experiences with interdisciplinary teaching across the demographic variables. The 95 % CIs show no observable differences across any of the variables.

Overall changes from pretest to posttest scores

To examine if the overall changes were statistically significant, as addressed by the first research question, the differences in scores from the pretest to the posttest for attitudes toward interdisciplinary teaching and resistance to change were examined using two-tailed paired sample *t* test. As the study was a within-subjects design with two levels, the pretest and the posttest, the paired *t* test was the most appropriate analysis (Gliner and Morgan 2000). The results indicated that there were no statistically significant differences between the pretest and the posttest of attitude to interdisciplinary teaching.

Wilcoxon signed ranks tests were used to compare teaching satisfaction and attitude toward teamwork between the pre and post administration. This analysis was selected due to the violation of the assumption of normality, as indicated by Shapiro–Wilk statistics (see Appendix 3), for both constructs (Gliner and Morgan 2000). Of 29 participants, 15 teachers' responses showed negative change in teaching satisfaction, 12 teachers positive change, and 2 with no change, the change was not significant. Similarly, for the 29

Table 3 Means, standard deviations, and 95 % CI for prior experience with interdisciplinary teaching (years) across school level, gender, education level, and discipline taught (N = 29)

Variable	Prior experience with interdisciplinary teaching (years)			
	M	SD	95 % CI	
			L	U
School level				
Middle school	10.29	2.34	9.09	11.50
High school	10.25	1.71	9.16	11.34
Gender				
Male	10.46	2.03	9.24	11.69
Female	10.13	2.16	8.98	11.27
Education level				
BA/BS	10.43	1.72	8.84	12.02
MA/MS	10.23	2.20	9.25	11.20
Discipline taught				
Science	11.00	2.37	9.74	12.26
Tech./Eng.	9.14	1.07	8.15	10.13
Math	9.67	1.37	8.23	11.10

participants, 12 teachers' responses indicated negative change in attitude to teamwork, 11 teachers' positive change, and 6 no change. No significant difference were detected between the two administrations.

Changes from pretest to posttest across demographic variables

Analyses were conducted to examine changes across teachers' gender, school level, education level, and discipline taught, as addressed by research question two. Figure 4 shows the changes in attitudes to interdisciplinary, attitudes to teamwork, teaching satisfaction, and resistance to change across each of the four demographic variables. In addition, Table 4 presents means, standard deviations, and 95 % CIs of the changes in the four constructs across the demographic variables. The table shows that each 95 % CI includes zero indicating non-significant change, except for the change in attitude to teamwork for math teachers, 95 % CI [.15, 3.51].

The findings, overall, show that while teachers, across demographic variables, entered with varied attitudes to interdisciplinary teaching (means ranged from 52.50 to 59.71, pretest), there was less variation in their attitudes (means range from 55.00 to 56.47) at posttest), as shown in Fig. 4. In addition, while there were less positive attitudes to interdisciplinary teaching, attitudes to teamwork, and teaching satisfaction among participants from middle schools, participants from high schools showed more positive responses in all three constructs. In resistance to change, while there was more favorable attitudes among participants from middle schools, there was a decline among teachers from high schools. Likewise, females showed an increase in resistance to change and less positive attitudes toward interdisciplinary teaching, attitudes toward teamwork, and teaching satisfaction, which is contrary to male teachers except for attitudes to teamwork where there was a slight decline. The analysis across education level indicated that participants with graduate degrees showed increased teaching satisfaction and resistance to change in contrast to teachers with undergraduate degrees where teaching satisfaction and resistance to change decreased, and attitudes to interdisciplinary teaching and attitudes to teamwork increased. In contrast to math teachers, science teachers showed an increase in resistance to change and a decline in attitudes to interdisciplinary teaching and to teamwork and lower teaching satisfaction.

Associations between changes

Prior to the analysis, the Shapiro–Wilk test was used to examine the assumption of normality for all variables. Since all variables were normally distributed (see Appendix 3), Pearson's correlations were the most appropriate analysis (Gliner and Morgan 2000) to investigate if there were statistically significant associations between changes: in attitudes toward interdisciplinary teaching, attitudes toward teamwork, teaching satisfaction, and teacher resistance to change. The associations between changes is addressed in research question three. Table 5 shows the inter-correlations, means, and standard deviations for each of these changes.

Four of the six pairs of variables were significantly correlated. Change in attitudes to interdisciplinary teaching was strongly and positively correlated with both change in attitudes to teamwork $r(28) = .41$, $p = .03$, and change in teaching satisfaction, $r(28) = .37$, $p = .049$. Change in attitudes to interdisciplinary teaching had a significant and negative correlation with change in resistance to change $r(28) = -.40$, $p = .03$. The fourth significant correlation was between change in attitudes to teamwork and change in

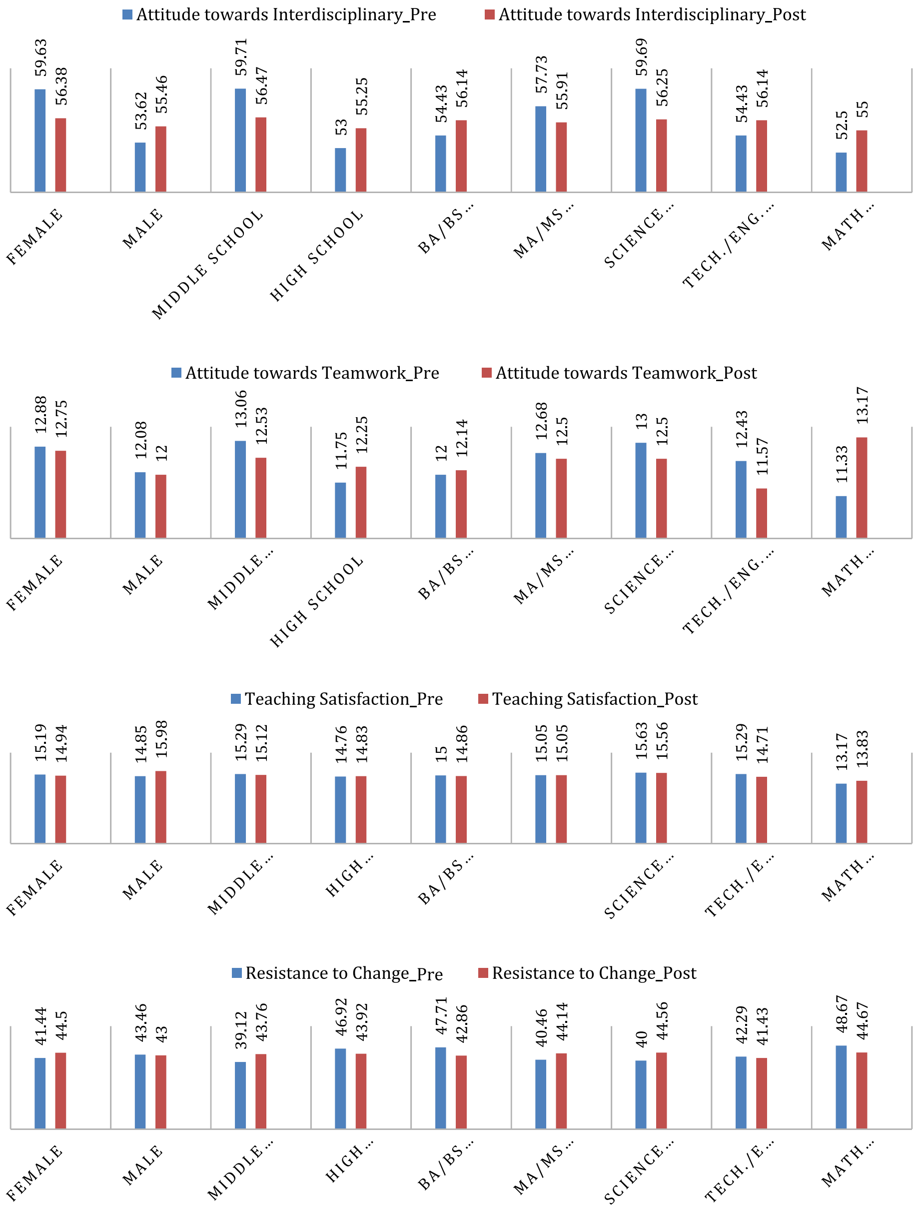

Fig. 4 Pre and post analysis across teachers' gender, school level, education level, and discipline taught

teaching satisfaction, $r(28) = .46$, $p = .01$. Using Cohen's (1988) guidelines, the effect sizes for these four correlations were considered medium to large.

Qualitative findings

The findings from qualitative analysis were organized around the two research questions, which investigated successes as shown in Table 6, and challenges of teachers' experiences

Table 4 Means, standard deviations, and 95 % confidence intervals for change in attitude toward interdisciplinary teaching, change in attitude toward teamwork, change in resistance to change, and change in teaching satisfaction across teachers' school level, gender, education level, and discipline taught (N = 29)

Source	Change in attitude to interdisciplinary teaching (post–pre)				Change in attitude to teamwork (post–pre)				Change in resistance to change (post–pre)				Change in teaching satisfaction (post–pre)			
Teachers'	M	SD	95 % CI		M	SD	95 % CI		M	SD	95 % CI		M	SD	95 % CI	
			L	U			L	U			L	U			L	U
School level																
Middle school	−3.24	7.73	−7.21	.74	−0.53	3.02	−2.08	1.03	4.65	8.52	.27	9.03	−0.18	2.38	−1.40	1.05
High school	2.25	5.28	−1.10	5.60	0.50	2.28	−.95	1.95	−3.00	9.13	−8.80	2.80	0.17	3.67	−2.16	2.49
Gender																
Male	1.85	6.12	−1.85	5.55	−0.08	3.20	−2.01	1.86	−0.46	8.03	−5.31	4.39	0.23	3.47	−1.86	2.33
Female	−3.25	7.48	−7.24	.74	−0.13	2.42	−1.41	1.16	3.06	10.41	−2.49	8.61	−0.25	2.49	−1.58	1.08
Education level																
BA/BS	1.71	7.61	−5.32	8.75	0.14	2.19	−1.89	2.17	−4.86	8.19	−12.44	2.72	−0.14	1.77	−1.78	1.50
MA/MS	−1.32	2.94	−4.97	1.33	−0.18	2.93	−1.48	1.12	3.50	9.04	−.51	7.51	0.00	3.24	−1.44	1.44
Discipline taught																
Science	−3.44	3.33	−7.59	.71	−0.50	3.08	−2.14	1.14	4.56	9.19	−.33	9.46	−0.06	2.32	−1.30	1.18
Tech./Eng.	1.71	4.23	−2.20	5.03	−.86	2.12	−2.81	1.10	−.86	10.59	−10.97	9.25	−0.57	4.76	−4.97	3.83
Math	2.50	6.89	−4.73	9.73	1.83	1.60	.15	3.51	−4.00	5.22	−9.47	1.47	0.67	1.86	−1.29	2.62

Table 5 Means, standard deviations, and inter-correlations for change in attitudes toward interdisciplinary teaching, change in attitude toward teamwork, change in resistance to change, and change in teaching satisfaction (N = 29)

Construct	M	SD	1	2	3	4
1. Change in attitude toward interdisciplinary teaching	−.97	7.26		.41[a]	.37[a]	.40[a]
2. Change in attitude toward teamwork	−.10	2.74			−.34	.46[a]
3. Change in resistance to change	1.48	9.43				−.18
4. Change in teaching satisfaction	−.035	2.92				

[a] Correlation is significant at the 0.05 level (2-tailed)

Table 6 Successes with implementation process: themes and teachers' quotes by school level

Themes	Teacher's quotes illustrating theme	School level
Cross-content collaboration	"We meet every week about 20 min, we feel more collegial", "collaboration among teachers", "we are excited to see students working collaboratively as researchers"	Middle school and high school
Forming students' teams	"Kids got into groups and present habits", "we did team names and logos", "team building activities went well", "great teamwork, wonderful mix of kids (equity), balance of 7th and 8th grades"	MIDDLE SCHOOL and high school
Collaboration with fellows	"Going well and great help from fellows"	High school
Students' excitement	"Students are excited to develop their own ideas and work in groups", "Students asking: when we are doing STEM again?", "exposing students to new content", "Cooperation among classes-freshman and senior", "no one checked out", "Students increased level of inquiry on their own"	Middle school and HIGH SCHOOL
Students-fellows excitement	"Students are excited to talk to fellows"	Middle school

All upper case LETTERS indicate the school level where more teachers reported these themes

shown in Table 7, relative to the school level–middle school or high school. Upper case letters indicate the school level of the teachers who reported more examples for each identified theme.

Discussion

Overall changes between pretest and posttest

The findings indicated that there was no overall significant change from the pretest to the posttest administrations in teachers' attitudes to interdisciplinary teaching, attitudes to teamwork, teaching satisfaction, or resistance to change. This finding is consistent with published research attempting to measure changes in teachers attitudes. For example, Tal et al. (2001) found that a 1-year-period is not enough for a significant change in attitudes within teachers' PD. Bolster (1983) asserted that teachers do not change their practices quickly. Guskey (2002a, b) indicated change requires both time and effort. The requirement of time and energy to learn the new practices and to plan for implementing them add

Table 7 Challenges with implementation process: themes and teachers' quotes by school level

Codes	Teacher's quotes illustrating theme	School level
Students' background knowledge and skills	"We are worried about what students will come up with. Worried about their background", "nightmare about having students in the lab"	Middle school
Students' buy-in	"Students not convinced of curricular tie-in"	High school
Securing supplies/expenses	"Types of supplies and how we can get them on time", "Students ask: what types of supplies I can bring from home?" "Students ask: do we have to pay for supplies?", "ordering, notebook onto supply list", "expenses for supplies", "budget for supplies"	MIDDLE SCHOOL and high school
Lack of experience	"Kids look at us right and not right and we don't have past experience"	Middle school
Students' group (planning, support and evaluation)	"Make them meet for short term goals", "Keeping them accountable", "moving them incrementally", "keeping kids motivated for the whole semester", "creating groups of diverse students", "how to evaluate kids who are into groups", "getting everybody participating", "creating groups based on student diversity-Leadership-IEP'S"	MIDDLE SCHOOL and high school
Using fellows	"Hard to schedule using fellow", "assigning work for the fellow is a work for us" "drop in create a lot of work"	MIDDLE SCHOOL and high school
Time limit	"How to make time available is a big challenge", "Issues with allocating time for: the project, collaboration between 3 teachers, covering the required content"	Middle school high school
Meeting mandated requirements	"Ensuring that students will be prepared for the mandated tests" "attaining a balance between doing STEM well and required content well"	High school
Cross-content collaboration	"No common planning with other teachers", "preparation and planning with other teachers"	Middle school

All upper case LETTERS indicate the school level where more teachers reported these themes

to teachers' workload, bring a certain amount of anxiety, so teachers might become reluctant to adopt new practices. This may be the case with any PD program associated with curriculum reform implementation. For example, Huberman found in a case study of one school implementing PD to prepare teachers to implement a reading program that it is typical for teachers to experience difficulties during the early stage of the implementation of a new program, particularly the first 6 months. He described this as "a period of high anxiety and confusion" (as cited in Fullan 1985, p. 393). He mentioned

> "teachers, trainers and administrators all talk of a 'difficult', 'overwhelming', sometimes 'humiliating' experience during the first six months…(After six months) concern for understanding the structure and rationale of the program grows as behavioral mastery over its parts is achieved" (as cited in Fullan 1985, p. 393). This indicates the advantage of a relatively longer period for PD programs.

As teachers were self-selected into the program, it is possible that attitudes toward interdisciplinary teaching were already favorable, and therefore little or no change would be detected. With a scale score of 3, the midpoint of each of the four scales representing a middle ground, then teachers, on average, can be said to be reasonably satisfied about teaching, have low resistance to change, and have favorable attitudes to both interdisciplinary teaching and to teamwork. However, by comparing the means between the pretest and the posttest of each of the previous analysis across all participants, regardless of their demographics, there were less positive attitudes toward interdisciplinary teaching and to teamwork and for teaching satisfaction. In contrast, resistance to change increased. Further analysis of the change in attitude to interdisciplinary teaching across teachers' gender, school level, education level, and discipline taught was conducted, there were observable variations in the changes.

Changes across gender and school level

While both female teachers and middle school teachers as a whole, compared with male teachers and high school teachers, entered with more positive attitude toward both interdisciplinary teaching and teamwork, a higher level of teaching satisfaction, and a lower level of resistance to change, the impact of their participations in the PD was dissimilar to that of male teachers and high school teachers. These findings turned to the opposite by the end of the PD. In addition, while male teachers and high schools teachers demonstrated positive change in attitude toward interdisciplinary teaching and toward teamwork and their teaching satisfaction; female teachers and middle school teachers' scores declined. While the resistance to change decreased slightly for male and high school teachers, female and middle school teachers demonstrated slight increases.

Studies that assessed changes of teachers' attitudes toward interdisciplinary teaching over the time involved in a PD experience are elusive and rare in the research literature. There were few studies that assessed teachers' perceptions of the importance of infusing engineering into K-12 curriculum or evaluated the changes in teaching practices. For example, Yaşar et al. (2006) surveyed a sample of 98 K-12 science teachers in Arizona about their perceptions of engineering as being important to be taught and their familiarity with teaching design, engineering, and technology (DET). Both female teachers and middle school teachers rated the importance of DET to be significantly higher than did male teachers and high school teachers. In addition, female teachers and middle school teachers had more positive perceptions toward integrating DET into science curricula and more interest to learn about DET. However, the study was a non-experimental with data collected at a single time without a PD experience intervention to examine change.

Penuel et al. (2007) found no statistically significant difference between middle school teachers and high school teachers in program implementation and changes in teaching practices. Middle school teachers had prepared more for inquiry. This contrary finding can be explained by the outcomes of the qualitative analysis, which will be discussed in a later section. One of the major challenges for middle school teachers, not indicated by high school teachers, was planning and preparing with teachers of other disciplines.

Changes across discipline taught

Science teachers as a whole began with more favorable attitudes toward both interdisciplinary teaching and teamwork, higher levels of teaching satisfaction, and lower levels of resistance to change, their experiences with PD were different from the technology/engineering teachers and math teachers who showed growth in all constructs, science teachers exited with lower attitudinal scores, lower teaching satisfaction, and increased resistance to change. These findings were similar to previous research. For example, Yaşar et al. (2006) found that science teachers had very low confidence to integrate DET. From a survey of 40 teachers at one high school, science teachers expressed slightly lower interest in implementing interdisciplinary curriculum compared to mathematics and technology teachers (Bayer 2009). This suggests science teachers may need specific types of support to integrate engineering and technology into science curricula as suggested by the Next Generation Science Standards.

Changes across teachers education level

Although teachers with undergraduate degrees entered with lower attitude scores for interdisciplinary teaching and teamwork, they demonstrated growth in both attitudes. However, the trends were reversed for teachers with graduate degrees. Likewise, while teachers with undergraduate degrees became less resistant to change, teachers with graduate degrees became more resistant. The researchers could not identify any previous studies with a similar analyses. However, by looking at means and medians shown in Table 1, teachers with graduate degrees were more experienced compared to teachers with undergraduate degrees. This implies that more experienced teachers as a whole demonstrated declines in attitudes to interdisciplinary teaching. This finding is consistent with previous research. For example, Yaşar et al. (2006) found that experienced science teachers had less interest in learning about DET and the interest decreased as their teaching experience increased. Teachers with 11 or more years of science teaching experience considered teacher training as a barrier in integrating DET into the existing curriculum.

Associations between change in attitudes toward interdisciplinary teaching and changes in other constructs

This study found a significant positive association between change in attitudes to interdisciplinary teaching and change in attitudes to teamwork. This is consistent with findings from the research literature. For example, from a survey of 3250 Australian teachers who participated in PD programs, Ingvarson et al. (2005) reported that impact on teachers' knowledge and practices was significantly associated with the level of professional community in the school. Brown et al. (2011) indicated that 90 % (111 of 125) of teacher participants, who did not show any improvement, stated that they did not collaborate with teachers in other STEM disciplines. Another study Zinn (1997) suggested that discussions and interactions among colleagues enhanced learning and development.

The findings showed that teaching satisfaction has a significant and positive correlation with attitudes to interdisciplinary teaching. Teachers who demonstrated positive change in teaching satisfaction also demonstrated positive change in attitude to interdisciplinary teaching. This finding is consistent with the outcomes of studies as Ostroff (1992) reported moderate correlations between teaching satisfaction, commitment to learning, and performance. In addition, satisfaction with on-the-job supervisory processes improved teacher change (Nir and Bogler 2008). Teachers prefer supervisory processes that are not revealed to others, feedback that meet their needs and expectations, and professional processes occurring within their schools.

Discussion of qualitative findings

The analysis of qualitative data showed some commonalities and differences between middle school and high school teachers. Teachers from middle and high schools considered cross-content collaboration among teachers as an important success. However, high school teachers talked about their contact with the research fellows assigned to assist them in integrating new STEM content, middle school teachers reported only students-fellows communication. Challenges with using research fellows was reported by teachers from five schools, four of them were middle schools. While middle school teachers limited their description about their students' successes to 'getting well into teams', high school teachers went beyond by describing what student teams had accomplished and how they were collaborating.

The most important challenges reported by middle school teachers was their limited experiences with engineering design as opposed to inquiry based learning, students' weak background of knowledge and skills, and cross-content collaboration among teachers. High school teachers, however, indicated that students' buy-in and meeting the state mandated content requirements (content standards) as the biggest challenges. Both middle school teachers and high school teachers saw securing supplies and expenses, time constraints, and group support and evaluation as significant challenges. Middle school teachers more often reported these issues. These findings are consistent with previous research as Avery and Reeve (2013), in their case study of four high school teachers who participated in a long term PD program, identified evaluation of student group work and standards-based pressures as the most addressed concerns by teachers. Bayer (2009), a study of 40 teachers, reported that 84.8 % of high school teachers agreed that lack of time, money, or other resources made implementing interdisciplinary curriculum challenging, and 66.7 % of teachers agreed that graduation standards were another challenge.

The qualitative findings help to explain the quantitative findings for middle school teachers. The less positive attitudes toward interdisciplinary teaching among middle school teachers could be attributed to the limited amount and frequencies of communication with the fellows and with each other. This as well could explain the change in their attitudes to teamwork. Table 8 presents an integrative look of the quantitative and qualitative findings.

Table 8 Integration of quantitative and qualitative findings

School level	Quantitative findings (survey)	Qualitative findings (meetings)
Middle school	Decrease in Attitude to interdisciplinary teaching Attitude to teamwork Teaching satisfaction Increase in Resistance to change	The main challenges were Using fellows Cross-content collaborations
High school	Increase in Attitude to interdisciplinary teaching Attitude to teamwork Teaching satisfaction Decrease in Resistance to change	The reported successes were Teacher-fellow communications Cross-content collaborations

Implications

Although the study did not find significant differences in attitudes between the pretest and the posttest, there are useful and practical implications for PD program developers, administrators, and teachers. Although teachers of different disciplines, genders/identities, and school levels may benefit from similar overall PD structures, there are some unique challenges to be addressed for each particular group (Zwiep and Benken 2013).

Program developers must ensure that PD is comprehensive enough and flexible enough to meet diverse teacher, school, and student needs (Custer and Daugherty 2009), particularly science teachers since they are the largest population available for implementing STEM education (Bayer 2009). Penuel et al. (2007) found from a Hierarchal Linear Modeling (HLM) analysis of survey data collected from 454 science teachers that providing equipment and technology support were significant contributors to program implementation and to changes in science teaching practice. Supovitz and Turner (2000) found that science teachers need a relatively long duration of PD to develop "investigative culture" in their classrooms. Zwiep and Benken (2013) found that the impact of PD for math teachers was different from science teachers relative to the nature of their discipline and their perceptions (e.g., confidence) and knowledge of content.

Program developers should provide opportunities for teachers to enhance teamwork skills. This is particularly important because research shows a positive association between level of teamwork skills and attitudes to teamwork. Park et al. (2005) reported teachers with teamwork skills showed higher levels of team commitment. Program conductors should also work closely with each teacher participants to understand and remove barriers to promote change. Brown et al. (2011) found among teachers who understood and valued STEM education, <20 % implemented STEM.

Another important implication is the importance of the involvement of school administrators in the STEM PD programs. The designers should create opportunities and roles for school administrators to increase their familiarity with STEM education and involve them. Administration support of teacher change is consistent with a study conducted by Brown et al. (2011), from a survey of 200 teachers and administrators, <50 % of administrators "(with teachers in their building participating in a STEM-focused Master's Degree)" understood the STEM concept and/or could describe it. Such school administrators are less likely to provide adequate support for the implementation of interdisciplinary teaching. Teachers need to be aware that collaboration and discussions with their colleagues enhance their learning and understanding of new programs and help them to successfully integrate the learning into their existing classroom practices.

Limitations

The study explored the relationships among the change in attitudes toward interdisciplinary teaching and the changes in attitudes toward teamwork, teaching satisfaction, and resistance to change over the PD period. The study could only describe the trends in changes from the pretest to the posttest. It could not identify the causes for the improvement or the decline. This was mainly because of the non-probability selection of the sample, no random assignment of the participants into groups, and the lack of a control group (Shadish and Cook 2002). This affects the generalizability of the findings and limits the interpretation of the results. Additionally, difference from the pretest to posttest might be due to maturation or history (Shadish and Cook 2002). This is particularly because of the interval (12–15 weeks) between the pretest and the posttest.

Another limitation is the use of two different procedures for data collection; direct survey for the pretest, and emailed survey for the posttest. This might be the reason for getting different respondents in the pretest and the posttest. The seven participants who responded to the pretest and did not respond to the posttest might not have checked their emails during the data collection period. Work of Dillman and Smyth (2014) indicated their analysis of various studies using mixed mode surveys established consistency in participants' responses among visual modes of surveys including face-to-face surveys, mailed surveys, and web surveys. They only cautioned against mixing aural and visual modes, which was not the case in this study.

Further, about one-seventh of the participants did not respond at all (n = 6), and they may be the least motivated or cooperative participants. The response rate was 85.7 % for the pretest, and 83.3 % for the posttest. By taking into account those who responded in both the pretest and the posttest, the overall response rate was 69 %, which may be a threat to the internal validity of the study. The sample size (n = 29) may have reduced the statistical conclusion validity and the power of the tests (Shadish and Cook 2002). The validity of the findings depend on the respondents' understanding of themselves and their willingness to give frank and honest answers (Gliner and Morgan 2000).

Future research

A future study may consider examining challenges across disciplines taught especially ones experienced by science teachers to learn about how to facilitate STEM implementation. Other questions of important consideration include: Will the cross-content collaborations among teachers continue, particularly for mathematics teachers after they experienced positive outcomes of interdisciplinary teaching? What type of support would facilitate interdisciplinary teaching in middle schools and high schools? What interdisciplinary teaching are these teachers doing 2 years later? How to promote cross-content collaborations among teachers?

Appendix 1: Results of paired samples *t* tests for attitudes to interdisciplinary teaching and resistance to change

See Table 9.

Table 9 Results of paired samples *t* tests for attitudes to interdisciplinary teaching and resistance to change (N = 29)

Source	M	SD	*t*	*df*	*p*	95 % CI	
						Lower	Upper
Pair 1: attitude to interdisciplinary							
Pretest	56.93	7.19					
Posttest	55.97	6.88	−.72	28	.48	−3.73	1.80
Pair 2: resistance to change							
Pretest	42.34	8.42	.85	28	.40	−2.10	5.07
Posttest	43.83	5.73					

Appendix 2: Characteristics of students in participating middle schools and high schools as in school year 2013/2014

See Table 10.

Table 10 Students' characteristics in participating middle schools and high schools in school year 2013/2014

Student characteristics	Middle schools (%)	High schools (%)
Ethnicity		
White	55	51
Hispanic	20	19
Black	11	16
Asian	8	9
Student groups		
Economically disadvantaged	28	26
English language learner	8	6
Talented/gifted	12	11
Performance		
Reading	77	72
Writing	64	59
Math	62	45
Science	61	58

Appendix 3: Results of normality tests

See Table 11.

Table 11 Tests of normality (N = 29)

Source	Kolmogorov–Smirnov[a]			Shapiro–Wilk		
	Statistic	*df*	Sig.	Statistic	*df*	Sig.
Pretest						
Attitudes to team work	.179	29	.018	.917	29	.025
Attitudes to interdisciplinary teaching	.118	29	.200*	.967	29	.476
Resistance to change	.103	29	.200*	.986	29	.962
Teaching satisfaction	.205	29	.003	.863	29	.001
Posttest						
Resistance to change	.075	29	.200*	.983	29	.903
Teaching satisfaction	.146	29	.115	.936	29	.080
Attitude to interdisciplinary teaching	.147	29	.109	.944	29	.125
Attitude to team work	.166	29	.039	.916	29	.024

Table 11 continued

Source	Kolmogorov–Smirnov[a]			Shapiro–Wilk		
	Statistic	*df*	Sig.	Statistic	*df*	Sig.
Posttest–pretest						
Change in attitudes to interdisciplinary teaching	.101	29	.200*	.965	29	.427
Change in attitudes to team work	.107	29	.200*	.977	29	.771
Change in resistance to change	.076	29	.200*	.976	29	.733
Change in teaching satisfaction	.147	29	.110	.956	29	.255

* This is a lower bound of the true significance

[a] Lilliefors significance correction

References

Avalos, B. (2011). Teacher professional development in *Teaching and Teacher Education* over ten years. *Teaching and Teacher Education, 27*(1), 10–20.

Avery, Z. K., & Reeve, E. M. (2013). Developing effective STEM professional development programs. *Journal of Technology Education, 25*(1), 55–69.

Bartholomew, S. S., & Sandholtz, J. H. (2009). Competing views of teaching in a school–university partnership. *Teaching and Teacher Education*, *25*(1), 155–165.

Bayer, J. A. (2009). *Perceptions of science, mathematics, and technology education teachers on implementing an interdisciplinary curriculum at Blaine Senior High*. (Thesis). University of Wisconsin–Stout, Menomonie WI: Retrieved May 11, from http://www.uwstout.edu/lib/thesis/2009/2009bayerj.pdf; http://digital.library.wisc.edu/1793/42981

Boardman, A. G., & Woodruff, A. L. (2004). Teacher change and "high-stakes" assessment: What happens to professional development? *Teaching and Teacher Education, 20*(6), 545–557.

Bolster, A. S. (1983). Toward a more effective model of research on teaching. *Harvard Educational Review, 53*(3), 294–308.

Borko, H., Elliott, R., & Uchiyama, K. (2002). Professional development: A key to Kentucky's educational reform effort. *Teaching and Teacher Education, 18*(8), 969–987.

Breault, D. A., & Breault, R. (2010). Partnerships for preparing leaders: what can we learn from PDS research? *International Journal of Leadership in Education*, *13*(4), 437–454.

Brown, R., Brown, J., Reardon, K., & Merrill, C. (2011). Understanding STEM: Current perceptions. *Technology and Engineering Teacher, 70*(6), 5–9.

Chen, T., de Miranda, M., & Tobet, S. (2009). *A multidisciplinary research and technology program in biomedical engineering for discovery understanding of cell communication*, CSU GK-12 program, Colorado State University, Fort Collins CO. Retrieved March 15, from http://csu-gk12.engr.colostate.edu/

Cochran-Smith, M. (2001). The outcomes question in teacher education. *Teaching and Teacher Education, 17*(5), 527–546.

Cohen, J. (1988). *Statistical power analysis for the behavioral sciences* (2nd ed.). Hillsdale, NJ: Erlbaum.

Coskie, T. L., & Place, N. A. (2008). The National Board certification process as professional development: The potential for changed literacy practice. *Teaching and Teacher Education, 24*(7), 1893–1906.

Creswell, J. W. (2012). *Qualitative inquiry and research design: Choosing among five approaches* (3rd ed.). Los Angeles, CA: Sage Publications.

Custer, R. L., & Daugherty, J. L. (2009). *The nature and status of STEM professional development: Effective practices for secondary level engineering education*. Research in engineering and technology education. Logan, UT: National Center for Engineering and Technology Education. Department of Engineering Education, Utah State University, Retrieved May 11, from http://search.proquest.com/docview/1314332117?accountid=10223

Delandshere, G., & Arens, S. A. (2001). Representations of teaching and standards-based reform: Are we closing the debate about teacher education? *Teaching and Teacher Education, 17*(5), 547–566.

Demirtas, Z. (2010). Teachers' job satisfaction levels. *Procedia-Social and Behavioral Sciences, 9*, 1069–1073.

Desimone, L. M. (2009). Improving impact studies of teachers' professional development: Toward better conceptualizations and measures. *Educational Researcher, 38*(3), 181–199.
Dillman, D. A., & Smyth, J. D. (2014). *Internet, phone, mail, and mixed-mode surveys: The tailored design method* (4th ed.). Hoboken, NJ: Wiley. Retrieved May 11, from http://www.CA.eblib.com/EBLWeb/patron/?target=patron&extendedid=P_1762797_0
Field, A. (2009). *Discovering statistics using SPSS*. Thousand Oaks, CA: Sage publications.
Fullan, M. (1985). Change processes and strategies at the local level. *Elementary School Journal*, *85*(3), 391–421. Retrieved May 11, from http://search.proquest.com/docview/63390439?accountid=10223
Gliner, J. A., & Morgan, G. A. (2000). *Research methods in applied settings: An integrated approach to design and analysis*. Mahwah, NJ: Lawrence Erlbaum.
Goodlad, J. I. (1983). A study of schooling: Some implications for school improvement. *Phi Delta Kappan, 64*(8), 552–558.
Guskey, T. R. (2002a). Does it make a difference? Evaluating professional development. *Educational Leadership, 59*(6), 45–51.
Guskey, T. R. (2002b). Professional development and teacher change. *Teachers and Teaching: Theory and Practice, 8*(3), 381–391.
Henning, E. (2000). Walking with "barefoot" teachers: An ethnographically fashioned casebook. *Teaching and Teacher Education, 16*(1), 3–20.
Hernandez, P. R., Bodin, R., Elliott, J. W., Ibrahim, B., Rambo-Hernandez, K. E., Chen, T. W., & de Miranda, M. A. (2013). Connecting the STEM dots: Measuring the effect of an integrated engineering design intervention. *International Journal of Technology and Design Education, 24*(1), 107–120. doi:10.1007/s10798-013-9241-0.
Ho, C. L., & Au, W. T. (2006). Teaching satisfaction scale measuring job satisfaction of teachers. *Educational and Psychological Measurement, 66*(1), 172–185.
Ingvarson, L., Meiers, M., & Beavis, A. (2005). Factors affecting the impact of professional development programs on teachers' knowledge, practice, student outcomes & efficacy. *Education Policy Analysis Archives*, *13*(10). Retrieved May 10, 2014, from http://www.jstor.org/stable/20532527?seq=1#page_scan_tab_contents
International Technology Education Association. (2000). *Standards for technological literacy*. Reston, VA: International Technology Education Association.
Jaros, S. (2010). Commitment to organizational change: A critical review. *Journal of Change Management, 10*(1), 79–108.
Jurasaite-Harbison, E., & Rex, L. A. (2010). School cultures as contexts for informal teacher learning. *Teaching and Teacher Education, 26*(2), 267–277.
King, M. B. (2002). Professional development to promote school wide inquiry. *Teaching and Teacher Education, 18*(3), 243–257.
Knight, P. (2002). A systemic approach to professional development: Learning as practice. *Teaching and Teacher Education, 18*(3), 229–241.
Kraut, A. I., & Korman, A. K. (1999). *Evolving practices in human resource management: Responses to a changing world of work*. San Francisco, CA: Jossey-Bass Publishers.
Laboy-Rush, D. (2011). *Integrated STEM education through project-based learning*. STEM solutions manager at learning.com. Retrieved May 10, from http://www.rondout.k12.ny.us/common/pages/DisplayFile.aspx?itemId:p16466975
Langdon, D., McKittrick, G., Beede, D., Khan, B., & Doms, M. (2011). *STEM: Good jobs now and for the future*. ESA Issue Brief #03-11. Washington, DC: U.S. Department of Commerce, Economics and Statistics Administration.
Lovett, M. W., Lacerenza, L., De Palma, M., Benson, N. J., Steinbach, K. A., & Frijters, J. C. (2008). Preparing teachers to remediate reading disabilities in high school: What is needed for effective professional development? *Teaching and Teacher Education, 24*(4), 1083–1097.
Ma, X., & MacMillan, R. B. (1999). Influences of workplace conditions on teachers' job satisfaction. *The Journal of Educational Research, 93*(1), 39–47.
McIntyre, E., & Kyle, D. W. (2006). The success and failure of one mandated reform for young children. *Teaching and Teacher Education, 22*(8), 1130–1144.
Melville, W., & Wallace, J. (2007). Metaphorical duality: High school subject departments as both communities and organizations. *Teaching and Teacher Education, 23*(7), 1193–1205.
Miles, M. B., & Huberman, A. M. (1994). *Qualitative data analysis: An expanded sourcebook*. Sage.
Muijs, D., & Harris, A. (2006). Teacher led school improvement: Teacher leadership in the UK. *Teaching and Teacher Education, 22*(8), 961–972.
Next Generation Science Standards (NGSS) Lead States. (2013). *Next Generation Science Standards: For states, by states*. Washington, DC: The National Academies Press.

Nielsen, D. C., Barry, A. L., & Staab, P. T. (2008). Teachers' reflections of professional change during a literacy-reform initiative. *Teaching and Teacher Education, 24*(5), 1288–1303.
Nir, A. E., & Bogler, R. (2008). The antecedents of teacher satisfaction with professional development programs. *Teaching and Teacher Education, 24*(2), 377–386.
Oreg, S. (2003). Resistance to change: Developing an individual differences measure. *Journal of Applied Psychology, 88*(4), 680–693.
Ostroff, C. (1992). The relationship between satisfaction, attitudes, and performance: An organizational level analysis. *Journal of Applied Psychology*, *77*(6), 963.
Park, S., Henkin, A. B., & Egley, R. (2005). Teacher team commitment, teamwork and trust: Exploring associations. *Journal of Educational Administration, 43*(5), 462–479.
Park, S., Oliver, J. S., Johnson, T. S., Graham, P., & Oppong, N. K. (2007). Colleagues' roles in the professional development of teachers: Results from a research study of National Board certification. *Teaching and Teacher Education, 23*(4), 368–389.
Penuel, W. R., Fishman, B. J., Yamaguchi, R., & Gallagher, L. P. (2007). What makes professional development effective? Strategies that foster curriculum implementation. *American Educational Research Journal, 44*(4), 921–958.
Reyes, P., & Shin, H. S. (1995). Teacher commitment and job satisfaction: A causal analysis. *Journal of School Leadership, 5*(1), 22–39.
Rockland, R., Bloom, D. S., Carpinelli, J., Burr-Alexander, L., Hirsch, L. S., & Kimmel, H. (2010). Advancing the "E" in K-12 STEM education. *Journal of Technology Studies, 36*(1), 53–64.
Runhaar, P., Sanders, K., & Yang, H. (2010). Stimulating teachers' reflection and feedback asking: An interplay of self-efficacy, learning goal orientation, and transformational leadership. *Teaching and Teacher Education*, *26*(5), 1154–1161.
Sandholtz, J. H. (2002). Inservice training or professional development: Contrasting opportunities in a school/university partnership. *Teaching and Teacher Education, 18*(7), 815–830.
Sato, K., & Kleinsasser, R. C. (2004). Beliefs, practices, and interactions of teachers in a Japanese high school English department. *Teaching and Teacher Education, 20*(8), 797–816.
Shadish, W. R., & Cook, T. D. (2002). *Experimental and quasi-experimental designs for generalized causal inference*. Boston, MA: Houghton Mifflin.
Shaha, S. H., Lewis, V. K., O'Donnell, J. J., & Brown, D. H. (2004). Evaluating professional development in an approach to verifying program impact on teachers and students. *Journal of Research in Professional Learning,* The National Staff Development Council. Retrieved May 10, 2014 from http://cleveland.mspnet.org/index.cfm/11156
Shann, M. H. (1998). Professional commitment and satisfaction among teachers in urban middle schools. *The Journal of Educational Research, 92*(2), 67–73.
Skerrett, A. (2010). "There's going to be community. There's going to be knowledge": Designs for learning in a standardized age. *Teaching and Teacher Education, 26*(3), 648–655.
Smith, I. (2004). Continuing professional development and workplace learning 7: Human resource development—A tool for achieving organizational change. *Library Management, 25*(3), 148–151.
Smith, I. (2005). Continuing professional development and workplace learning 13: Resistance to change—Recognition and response. *Library Management, 26*(8/9), 519–522.
Snow-Gerono, J. L. (2008). Locating supervision—A reflective framework for negotiating tensions within conceptual and procedural foci for teacher development. *Teaching and Teacher Education, 24*(6), 1502–1515.
Supovitz, J. A., & Turner, H. M. (2000). The effects of professional development on science teaching practices and classroom culture. *Journal of Research in Science Teaching, 37*(9), 963–980.
Tal, R. T., Dori, Y. J., & Keiny, S. (2001). Assessing conceptual change of teachers involved in STES education and curriculum development—The STEMS project approach. *International Journal of Science Education, 23*(3), 247–262.
Yaşar, Ş., Baker, D., Robinson-Kurpius, S., Krause, S., & Roberts, C. (2006). Development of a survey to assess K-12 teachers' perceptions of engineers and familiarity with teaching design, engineering, and Technology. *Journal of Engineering Education, 95*(3), 205–216.
Zinn, L. F. (1997). *Supports and barriers to teacher leadership: Reports of teacher leaders*. (Unpublished doctoral dissertation), University of Northern Colorado, Greeley, CO. Retrieved May 10, from http://eric.ed.gov/?id=ED408259
Zwiep, S., & Benken, B. M. (2013). Exploring teachers' knowledge and perceptions across mathematics and science through content-rich learning experiences in a professional development setting. *International Journal of Science and Mathematics Education, 11*(2), 299–324.