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Enhancing Self-Efficacy in Elementary Science Teaching With Professional Learning Communities

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Abstract Emerging from Bandura's Social Learning Theory, this study of in-service elementary school teachers examined the effects of sustained Professional Learning Communities (PLCs) on self-efficacy in science teaching. Based on mixed research methods, and a non-equivalent control group experimental design, the investigation explored changes in personal self-efficacy and outcome expectancy among teachers engaged in PLCs that featured Demonstration Laboratories, Lesson Study, and annual Summer Institutes. Significant changes favoring the experimental group were found on all quantitative measures of self-efficacy. Structured clinical interviews revealed that observed changes were largely attributable to a wide range of direct (mastery) and vicarious experiences, as well as emotional reinforcement and social persuasion.

Keywords Self-efficacy · Science teaching · Professional Learning Community

Introduction

Decades of research in elementary science teaching have produced a wealth of findings on such central questions as: How much time, effort and budgetary

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resources are typically devoted to science in the elementary school curriculum? What factors limit or constrain the quality and quantity of science instruction students receive? And most importantly, what can be done to ensure that elementary school children leave our classrooms with a level of scientific literacy that prepares them for further learning, and ultimately for competing in the international economy?

Not surprisingly, the overwhelming weight of evidence points to the teacher as the pivotal player in all of these issues. Unfortunately, with many exceptions, it appears that elementary school teachers have a largely negative attitude toward science, do not understand it, tend to be anxious about teaching it, allocate less classroom time to it than other subjects, rely heavily on recitation, worksheets and textbooks and, through their actions and emotions, pass their negative feelings on to their students (Duschl 1983; Shrigley 1974; Tilger 1990; Weiss et al. 2001). Because teachers often feel defensive and inadequately prepared to teach science, teacher educators have begun to explore where best to intervene in this potentially vicious cycle.

Substantial work on self-efficacy (Ashton and Webb 1986; Ramey-Gassert and Shroyer 1986) suggests that much can be done to improve elementary teaching and learning by enhancing teachers' perceptions of their own abilities to affect positive change in their work with children. More recently, several studies have demonstrated the value of extensive instructional support through PLCs (Britton 2010), Lesson Study (Sibbald 2009), and practical, hands-on experiences (Marcum and Heaston 2011). This study investigated the cumulative effects on self-efficacy of these interventions embodied in an intensive, 3 year, whole school, in-service professional development program.

Self-Efficacy in Elementary Science Teaching

Bandura's (1977, 1982) Social Learning Theory has served as a useful theoretical framework for exploring the effects of efforts designed to enhance self-efficacy in elementary science teachers. At the heart of the theory is the *self-efficacy* construct which Bandura describes as, "judgments about how well one can organize and execute courses of action required to deal with prospective situations that contain many ambiguous, unpredictable, and often stressful, elements." In basic terms, it is a measure of an individual's confidence in his or her ability to successfully engage in a complex task. Individuals who demonstrate high levels of self-efficacy approach difficult tasks as challenges to be overcome, setting high goals and persisting in efforts to achieve them. Those with lower levels of self-efficacy tend to avoid difficult or stressful tasks, setting lower goals and disengaging when faced with a challenge.

Bandura suggests that an individual's confidence reflects a self-assessment of one's ability to perform the task (*personal self-efficacy*) as well as his or her expectation that performing the task will result in a desirable outcome (*outcome expectancy*). In the context of science education, personal self-efficacy may be reflected in a teacher's confidence about implementing an elementary school science program or an inquiry-based science strategy. On the other hand, outcome expectancy may be a judgment about how likely it is that such a program or strategy, if appropriately implemented, will help children achieve a desired behavior or level of performance.

In theory, Bandura recognizes four "sources" or contributors to self-efficacy: *mastery experiences*, *vicarious experiences*, *physical and emotional states*, and *social persuasion.* For an elementary school teacher, an authentic opportunity to successfully practice teaching an inquiry-based science lesson might be expected to contribute substantially to a feeling of self-efficacy. Similarly, observing others skillfully teaching such a lesson could provide a vicarious experience, while actively participating in a community of like-minded professionals and receiving constructive feedback from peers could offer additional emotional support. Observing children successfully engage in lessons planned by a community of teachers suggests a way of confirming the positive outcomes of one's efforts.

Rather than a generalized personality trait, self-efficacy is viewed as contextually dependent. An elementary school teacher may, for example, demonstrate strong self-efficacy in English/language arts but less so in mathematics or social studies. Recognizing this, science educators have devoted considerable energy to developing and validating instruments for assessing self-efficacy in science teaching. The earliest and most widely used of these instruments is the *Science Teaching Efficacy Belief Instrument* (STEBI) developed by Riggs (1988) and Riggs and Enochs (1990). More recently, Smolleck et al. (2006) developed the *Teaching Science as Inquiry* (TSI) instrument based on the National Science Education Standards (NRC, 2000).

The emergence of the self-efficacy construct and the development of instruments to measure it have stimulated considerable research activity in the past 25 years. Accordingly, a significant effort has gone into characterizing individuals who express unusually high levels of self-efficacy in an effort to identify those who might make strong candidates for science teaching. Other efforts have focused on developing and implementing professional development models that might enhance self-efficacy in pre-service and in-service teachers. To date, this research program has generated a wealth of potentially useful knowledge.

Of the variables that have been investigated, a handful has been shown to correlate significantly with high levels of self-efficacy in science teaching, including: the number and quality of high school science courses taken (Mullholland et al. 2004; Watters and Ginns 1995); the number of college science courses taken (Enochs et al. 1995); conceptual understanding of central ideas in science (Schoone and Boone 1998); years of elementary school science teaching (Cantrell, Young and Moore 2003; Liu et al. 2003); a science teaching methods course (Yilmaz-Tuzun 2008), and a preference for activity-based rather than textbook-based instruction (Enochs et al. 1995). Not surprisingly, these findings suggest that the highest levels of self-efficacy are found in those who have a strong science background and an inclination to engage in reform-based teaching practices. Unfortunately, a large proportion of elementary school teachers and teacher candidates have inadequate preparation in and poor understanding of science, and tend to cling to "safe and familiar" teaching practices (Gess-Newsome 2001). This suggests a need to investigate new approaches to pre-service and in-service efforts as a way to mitigate these circumstances.

Self-Efficacy and Professional Learning

To date, efforts designed to enhance self-efficacy in elementary science teachers have focused overwhelmingly on preservice programs. The findings of these studies suggest that even relatively conventional science methods courses can boost teachers' self-efficacy (Hechter 2011; Palmer 2006). However, very substantial changes in self-efficacy have been reported in courses that implement each of the following components: community-based service learning (Cone 2009), cases and case methods (Yoon et al. 2006), scaffolded, student-directed inquiry (Liang and Richardson 2009), early field experiences in science teaching (Cannon and Scharmann 1996; McDonnough and Matkins 2010), and hands on science activities (Bleicher 2007).

Surprisingly, the number of studies devoted to the effects of in-service professional development programs on self-efficacy in science teaching has been modest. Bearing directly on the current study are recent reports focusing on several related, newly emerging approaches including, PLCs (Hamos and Bergin 2009; Lakshmanan et al. 2011), Japanese Lesson Study (Murata and Takahashi 2002; Puchner and Taylor 2006; Roberts 2010; Sibbald 2009), and university-based, Demonstration Laboratories (Marcum and Heaston 2011).

The term, "Professional Learning Community (PLC)," has been applied to "an ongoing process through which teachers and administrators work collaboratively to seek and share learning and to act on their learning, their goal being to enhance their effectiveness as professionals for students' benefit (Hord 1997)." Another definition suggests that a PLC constitutes a "group of people sharing and critically interrogating their practice in an ongoing, reflective, collaborative, inclusive, learning-oriented and growth-promoting way (McREL 2003)." However, it is defined, the PLC is a group of teachers and administrators meeting together on a regular basis to improve student learning. The methods used to accomplish these goals are diverse and varied.

In a comprehensive review of hundreds of papers spanning the years 1995–2010, Britton (2010) uncovered 50 well-designed and well-executed empirical studies that evaluated the effects of PLCs in STEM disciplines. Overall, he found that PLCs can: (1) engage teachers in discussion about science and science teaching or their understanding of it, (2) advance teachers' preparedness to teach science and improve their attitude toward it, and (3) increase teachers' focus on students' thinking in science.

One especially promising form of PLC is the Lesson Study, a version of professional development that is widely practiced at virtually all elementary schools in Japan and has been implemented at hundreds of sites across the United States in the past 15 years (Kelley 2002; Lewis 2002). In the formal practice of Lesson Study, 4–6 teachers working at the same school and grade level engage in weekly group meetings after school with an administrator and outside adviser. A complete Lesson Study cycle consists of several stages: (1) *research and preparation* (teachers jointly draw up a detailed plan for a study lesson), (2) *implementation* (one teacher presents the lesson to a real class while other members observe), (3) *reflection and improvement* (the group convenes to discuss, dissect and critically analyze their observations), and (4) *second implementation and reflection* (a different teacher presents the improved lesson to a second class while others observe, and the group reconvenes to discuss the lesson). Although this form of iterative improvement has been widely disseminated, only a handful of studies has explored its effects on teachers' self efficacy in STEM disciplines. The findings of two studies (Puchner and Taylor 2006; Sibbald 2009) suggest that Lesson Study can substantially boost self efficacy in the teaching of elementary school mathematics, while a third study (Roberts 2010) reported similar findings among secondary school science teachers.

The implementation of university-based, Demonstration Laboratories such as that in place at the National University of Singapore offers an additional model of professional development in elementary school science (www.science.nus.edu.sg/outreach/demolab/). Similar efforts are underway at Cal Poly San Luis Obispo (www.cesame.calpoly.edu/programs-lbdl.html) and California State University, Chico (www.csuchico.edu/cmse/k-12_student_programs/hands-on_lab.shtml). These laboratories offer hands on activities for elementary school children and are facilitated by pre-service university interns and observed by in-service teachers. In so doing, the laboratories provide a unique vehicle for concurrently developing and testing instructional materials, inducting novices into the teaching profession, and supporting in-service teachers who seek professional renewal. The CSU Chico "Hands On Lab", for example, has served 1,800 undergraduates, 500 teachers, and 27,000 school children since its inception in 2002. One study conducted at CSU Chico (Marcum and Heaston 2011), documented a positive and significant shift in self-efficacy among pre-service teachers working in the lab. To date however, no work has focused on the effects of this experience on in-service teachers.

Method

Participants

Participants in this study were 116 elementary school teachers representing two geographically proximate school districts in the Northern California Sacramento Valley. All K-5 teachers ($N = 55$) employed in the Grand Valley Unified School District[1] served as the experimental group. The comparison group ($N = 61$) of teachers was randomly chosen from nearby Mountain View Joint Unified School District. Grand Valley schools has a total enrollment of 900 students in grades K-5 of whom 56 % are Latino and 70 % are on free or reduced lunch regimes; about 40 % of all students are English Language Learners (ELLs). Although Mountain View is a considerably larger school district, the proportion of ELLs is about the same as Grand Valley, and the teaching staff at the elementary school level is quite comparable. In both communities the teacher population is quite stable and the average length of service approximates 15 years.

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[1] Grand Valley and Mountain View are pseudonyms for two public school districts located in Northern California.

Professional Learning Communities

Grade level PLCs were established at Grand Valley School, early in Year One. Each community consisted of 4–5 teachers who met biweekly to discuss, analyze, plan, implement and assess inquiry-based science lessons, and the integration of science with English/Language Arts instruction.

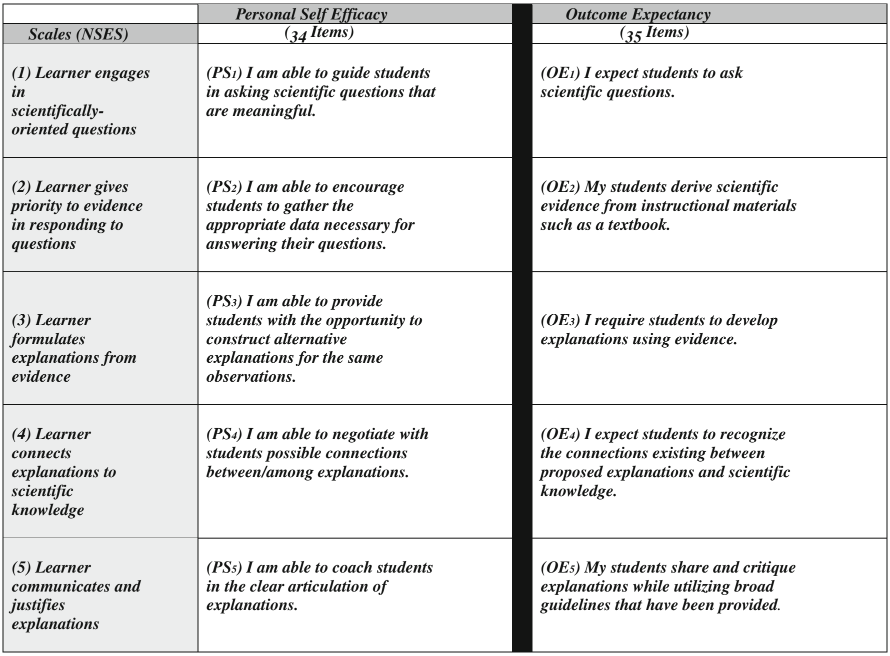
The centerpieces of PLC discussions were two university-based, *Demonstration Laboratories*, one designed for grades K-3 and another for grades 4–5. Each of these laboratories served as a model of excellence in curriculum design, implementation and assessment, as a center of innovation in teaching and learning, and as a platform for observing children and undergraduate interns. During the course of this project, each teacher and his or her class visited the Laboratory once a semester for a period of approximately 90 min each. During the visit, children moved through a series of stations which were designed to introduce conceptually-based science activities aligned to the state's elementary science standards. Teacher observations in the Demonstration Laboratory focused on children's prior knowledge and their understanding of scientific concepts. Facilitated discussions stemming from these Laboratory observations provided an entry point into the processes of *Lesson Study*.

A modified form of *Lesson Study* served as the model for professional collaboration. The work progressed in three stages: (1) Lesson Design and Introduction in the Demonstration Laboratory; (2) Grade Level Analysis and Planning; (3) Revision and Classroom Implementation. In sequence, teachers designed a series of basic, grade level lessons and observed university undergraduate interns who facilitated the lessons. Subsequently, teachers met to discuss and reflect on their observations and to consider critical issues of student learning. Finally, the original lessons were revised and implemented in their own classrooms. The revised lessons were observed by members of the grade level team and further discussion, revision and re-teaching ensued.

The Demonstration Laboratories and Lesson Study activities were supplemented by 1 week, full-time *Summer Institutes* in each of the 3 years of the project. The focus of the Summer Institutes varied by year, however over the 3 year period, time was devoted to: model lessons from the demonstration laboratories; hands on presentations of science concepts and conceptual understanding at the adult level; English language development strategies, with a particular emphasis on promoting oral discourse, and integrating science concepts with reading protocols and writing strategies. In all of these activities, an attempt was made to maintain and reinforce grade level PLC identities.

Measures

The TSI instrument (Smolleck et al. 2006) consists of 69 items which together purport to measure personal self-efficacy and outcome expectancy in elementary science teachers (Fig. 1). Based on five "essential features of classroom inquiry" identified in the National Science Education Standards (NRC, 2000), teachers respond to items using a 5-point Likert-type scale (5 = Strongly Agree; 4 = Agree; 3 = Uncertain; 2 = Disagree; 1 = Strongly Disagree). Scoring of the instrument



Scales (NSES)	Personal Self Efficacy (34 Items)	Outcome Expectancy (35 Items)
(1) Learner engages in scientifically-oriented questions	*(PS$_1$) I am able to guide students in asking scientific questions that are meaningful.*	*(OE$_1$) I expect students to ask scientific questions.*
(2) Learner gives priority to evidence in responding to questions	*(PS$_2$) I am able to encourage students to gather the appropriate data necessary for answering their questions.*	*(OE$_2$) My students derive scientific evidence from instructional materials such as a textbook.*
(3) Learner formulates explanations from evidence	*(PS$_3$) I am able to provide students with the opportunity to construct alternative explanations for the same observations.*	*(OE$_3$) I require students to develop explanations using evidence.*
(4) Learner connects explanations to scientific knowledge	*(PS$_4$) I am able to negotiate with students possible connections between/among explanations.*	*(OE$_4$) I expect students to recognize the connections existing between proposed explanations and scientific knowledge.*
(5) Learner communicates and justifies explanations	*(PS$_5$) I am able to coach students in the clear articulation of explanations.*	*(OE$_5$) My students share and critique explanations while utilizing broad guidelines that have been provided.*

Fig. 1 TSI: two dimensions, five scales and exemplary items

yields five subscale scores in each of personal self-efficacy (PS) and outcome expectancy (OE). The content and construct validity of the TSI were established in a multi-step, iterative, review and revision process using external experts as data sources. Cronbach's alpha (internal consistency) ranged from of .66 to .76 for personal self-efficacy and .60 to .78 for outcome expectancy. These ranges generally meet or exceed accepted standards for first generation instruments (Nunnally 1978). The reliability and validity estimates were established in an initial study of preservice elementary school teachers, however the instrument's authors subsequently modified the items to extend its use to work with in-service teachers.

In summarizing the implications of their work, the authors suggest that, “The TSI should be used in combination with other data collection techniques to more fully determine the self-efficacy beliefs of prospective teachers. These data collection techniques may include…interviews with prospective teachers, to more clearly understand their ideas and beliefs….” Accordingly, all participants in the experimental group were interviewed at the end of the academic year following the conclusion of the program.

Structured but flexible clinical interviews lasting approximately 20 min each were conducted to probe further into teachers' self-efficacy beliefs, and to explore their views about the PLC and its expected outcomes. The initial questions queried teachers about their instructional practices and how they had changed as a result of their participation in the project. Follow up questions converged on the extent to which they had implemented proposed instructional practices, the value of regular collaboration with peers, and the effects of Lesson Study and Demonstration Laboratory experiences on their classroom efforts. The interviews attempted to seek out, clarify and explain underlying connections between teachers' self-efficacy beliefs and their personal experiences before, during and after their participation. All interviews were audiotaped and responses were transcribed verbatim.

Data Collection and Analysis

The study employed mixed (quantitative and qualitative) methods and a general Non-Equivalent Control Group (NECG) experimental design. In this design, participants are selected from similar communities (i.e. school districts) but, because random assignment to treatments is not practicable, pre-treatment differences among groups are statistically adjusted. Qualitative data were analyzed through the constant comparison method (Denzin and Lincoln 2000).

The TSI instrument was administered online (using the SurveyGizmo^{T} platform) on two occasions, early in the Spring semester of Year One and again after the final summer institute in Year Three. The initial (pretest) data set represented the responses of 116 teachers, however absenteeism and normal attrition reduced the total to 89 complete pre and posttest response sets. Independent sample *t* tests were run to explore pretest differences among groups, and the analysis of covariance (ANCOVA) was employed to adjust for pretest differences and to document overall effects of the treatment. The Cohen's d statistic was employed to estimate effect sizes.

Clinical interviews were conducted 1 year after completion of the project. Responses were subjected to a constant comparison analysis based on grounded theory (Denzin and Lincoln 2000). An open coding system was employed to examine the initial interview responses. Subsequently, additional responses were reviewed and the coding system was modified to accommodate them. This iterative, inductive-deductive process of data review, analysis and coding was continued until a strong explanatory model emerged.

Results

In accordance with Social Learning Theory, we summarize the quantitative evidence for changes in self-efficacy occurring over the 3 year period encompassed by this study, employing the *Personal Self-efficacy* and *Outcome Expectancy* dimensions as organizing themes. Subsequently, we describe supporting, qualitative evidence for the underlying sources of self-efficacy with a focus on *mastery* and *vicarious experiences, emotional reinforcement* and *social persuasion.*

Personal Self Efficacy

Figure 2 summarizes the means, standard deviations and results of the data analyses for each of the five subscales (PS1 through PS5) associated with the Personal Self-efficacy dimension. A series of independent samples *t* tests was run on the *pre-test* scores in order to explore pre-existing differences between the experimental (Grand Valley) and comparison (Mountain View) groups. Results of these analyses revealed significant differences among groups on all five dimensions, favoring teachers in the comparison group. To adjust for differences in pre-test scores, an analysis of covariance (ANCOVA) was subsequently run on *post-test* scores using pre-test scores as the covariate. Overall, the findings reveal significant differences among groups on all five subscales ($p < .01$ on four subscales and $p < .05$ on one subscale), favoring teachers in the experimental group. Mean pre to posttest gains were .77 in the experimental group compared to .16 in the comparison group. The Cohen's d estimates of effect sizes ranged from 1.1 to 1.3 with a mean of 1.2, suggesting that the experimental treatment had a "large" effect. These findings document a significant shift in personal self-efficacy that can be attributed to the PLCs.

Outcome Expectancy

Figure 3 summarizes the descriptive statistics and data analyses for each of the five subscales (OE1 through OE5) associated with the Outcome Expectancy dimension. As with the previous analysis, a series of independent t tests was run on the *pre-test* scores and the results revealed significant differences among groups on all five dimensions, favoring teachers in the comparison group. To adjust for these differences, an analysis of covariance (ANCOVA) was run on *post-test* scores using pre-test scores as the covariate. The findings reveal significant differences among groups on all five subscales ($p < .01$ on two subscales and $p < .05$ on three subscales), favoring teachers in the experimental group. Mean pre to posttest gains were .73 in the experimental group compared to .18 in the comparison group. The Cohen's d estimates of effect sizes ranged from .8 to 1.2 with a mean of 1.0, suggesting that the treatment had a "large" effect. These findings document a significant shift in outcome expectancy attributable to the PLCs.

Overall Changes

A summary of the overall changes resulting from participation in the PLCs can be estimated by combining mean scores on the Personal Self-efficacy and Outcome Expectancy subscales. For teachers participating in the experimental (Grand Valley) group, the mean (and standard deviation) shift in pre to posttest scores was 3.04 (.58) to 3.79 (.41). For those in the comparison (Mountain View) group, the mean shift was 3.39 (.45) to 3.57 (.30).

Preparation, Fear and Avoidance

The TSI pre-test scores revealed low levels of self-efficacy among Grand Valley teachers; significantly lower even than teachers in Mountain View. Exploring this further, it soon became clear that one source of their diminished confidence was

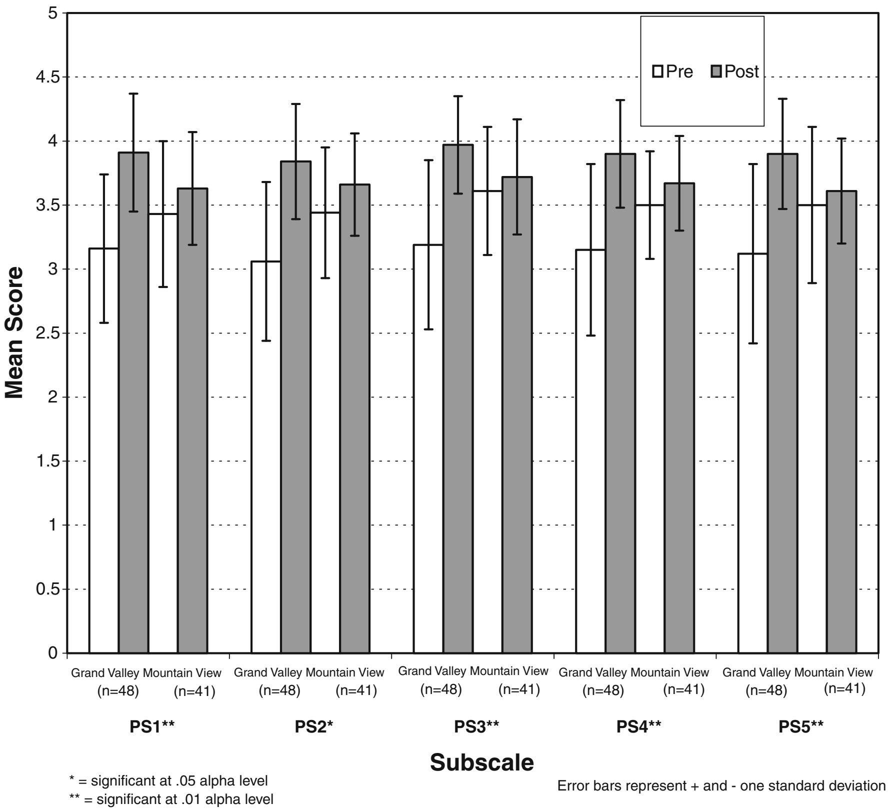


Fig. 2 TSI subscale scores: personal self-efficacy [PS] (means and SD)

poor academic preparation in science. For example, Lynn (2nd, 11 years)[2] poignantly described her own childhood feelings about science and her preservice preparation:

> Y'know as a kid I was afraid of science…. I never really was taught science. I never had it …I never experienced science before – ever….

In some cases the teachers' poor preparation didn't become a pressing issue until it was needed in their own classrooms. Penny [5th, 26 years] suggested that,

> the human body stuff is difficult if you've never taken anatomy, and that's not a required class for us. We're required to teach some heavy duty stuff in 5th grade.

In other cases, teachers readily admitted their anxiety about and avoidance of specific topical areas, especially in the physical sciences:

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[2] All teacher names are pseudonymous. Grade level and years of experience are designated in parentheses, e.g. Lynn (4th, 11 years).

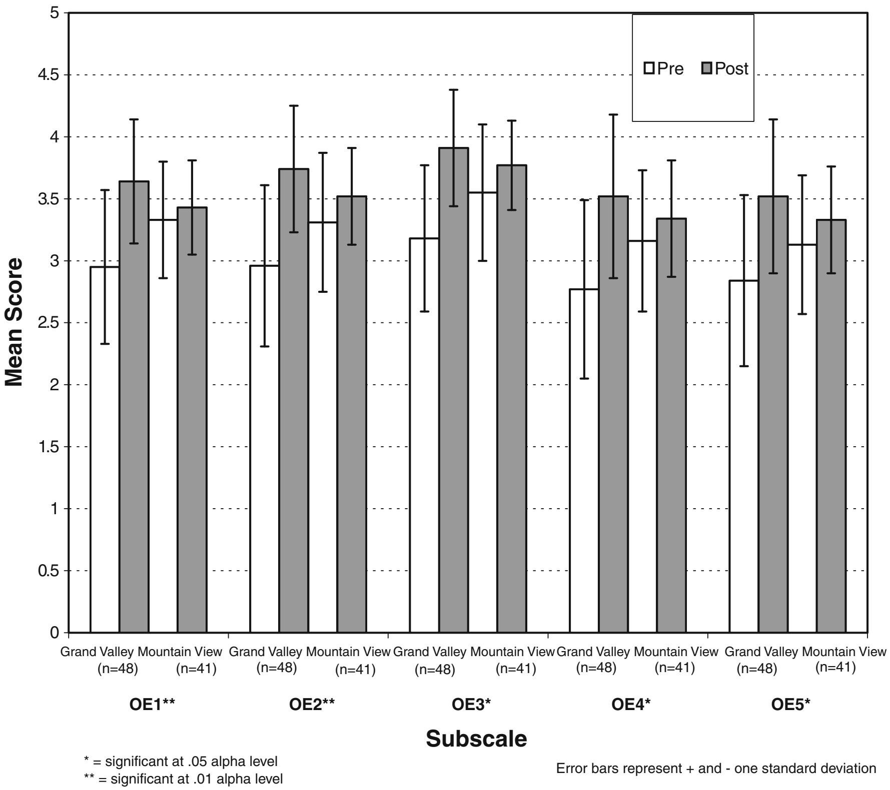

Fig. 3 TSI subscale scores: outcome expectancy [OE] (means and SD)

> Teachers tend to be afraid of tackling physical science….Life science was pretty much something that I've loved doing so I always do Life Science. I would definitely say that matter and energy was one thing I didn't really do… [Ashley, 3rd, 19 years]
>
> Of the 3 contents that we worked on, I think that the one that I learned the most about and I think I needed to learn was the physical science. I kind of avoided that because it wasn't something I was interested in… it was something that we tend to avoid; things we are not competent in sometimes. [Deborah, 3rd, 15 years]

Deborah went on to suggest that her feelings were shared by many of her colleagues:

> I think that teachers would say…if they had to give up one of the areas of the curriculum they're quickest to toss out science. I think they would chose social studies over science sometimes because social studies in some ways might be a little bit easier for them to teach. And a lot of people maybe didn't have a good experience with science, too, in their own education and they think they're not qualified to teach it.

In at least one instance, a teacher admitted that she left out science entirely, suggesting that she considered it less important than other subjects and felt constrained by time.

> I was doing no science, not making time for science because it seemed like one of those things you put to the corner and do if you have time. I was trained…that reading, writing and math are your number one priority and if you don't have time for anything else, don't worry about it. So I didn't do any science before this. [Marie 2nd, 16 years]

These assertions provide ample evidence that failure to master basic concepts, especially in the physical sciences, is undoubtedly one significant source of these teachers' diminished levels of self-efficacy in science teaching. They also suggest that some teachers act by avoiding and, in some cases, omitting science from the curriculum altogether. Said Marie,

> Y'know when you haven't been doing something and then you start doing something, it's a lot of work to try to figure out how to do it. It's much easier to stay in your routine. Especially when you don't know the subject area very well.

Empowerment

Despite their apparent fear and avoidance, Grand Valley teachers generally embraced the concept of PLCs and, when asked to discuss the effects of the PLCs on their own feelings about science, many participants described a strong sense of empowerment. Lynn expressed her new-found confidence as one of "I can do this":

> some of those things I can do like the seed cups and the [rain] gutters – I can do that – to where before science kind of scared me. Science wasn't my thing. I don't know how to do it…I don't know and you showed me that I can. It gave me a little bit of "I can do this".

In many instances the expression of empowerment was associated with a specific "hands on" activity which offered a kind of tangible and concrete, mastery experience. In reference to work on one physical science demonstration, Michelle's (1st, 4 years) success seemed to reinforce her emerging sense of self confidence.

> I think that it showed me how you can implement some of these science activities…I didn't have an idea of how to do that before. It helped me see how I could start to implement that in the classroom. …just getting me to "I can." It is possible to implement that in my classroom. Instead of feeling "Gosh, I don't know where to go with that".

In other instances, confidence seemed to grow out of an opportunity to watch others succeed. This vicarious experience was especially powerful as teachers observed undergraduate interns facilitating the science lessons with the teachers' own students in the Demonstration Laboratory.

> …there are times I'm not sure how I want to present something and watching [the interns] present it gives me that "oh, yeah, that would work" "oh, that was a fantastic way that you handled those kids, how you got them involved". It's fantastic…. [Miriam 5th, 4 years]
>
> I think for a lot of teachers, they see things that they can say, "Oh, I can do that in my classroom" when they see the student teachers [undergraduate interns] doing it with the small groups, it makes it not so scary to try it in your classroom. …you have a lot of teachers that they're comfortable reading out of the science book and doing packets but when it comes to doing hands-on things, you know it's kind of out of their comfort zone. This let them see…. "Oh, I can do that in my classroom". [Ashley, 3rd, 19 years]

Collaboration

The opportunity to collaborate in the design, implementation and assessment of a science lesson proved to be a powerful experience for many participants. The power of the cooperative groups seemed to emerge from the emotional support they provide and from the social persuasion that comes with negotiating differences of opinion.

> Designing the lesson plan together was a wonderful task….we designed this fabulous lesson, it was just invaluable. Being able to pick each others' brains to see different takes on something. We'll all look at the same thing and have a different opinion about it. And then watching each other deliver the lesson plan and then we tweaked it slightly and it worked better. We still get together and revisit lessons, share curriculum, share ideas. [Misty, 5th, 15 years]

This form of collaborative effort and the emotional reinforcement it engendered seemed to be an unexpected outcome for some teachers. In at least one instance it encouraged teachers to expand an existing cooperative arrangement to include science teaching in their group work.

> It's funny, I think some of us have become closer because of it and there's, I know me and two others, who really share some of the science stuff we have….we seem to be more interested in some things and we share them…. I guess the three of us probably collaborated a lot before, but we do it with science more now. [Lynn, 2nd, 11 years]

Outcomes

In addition to the emotional reinforcement it offered, many participants commented on the positive outcomes they observed in the children. In some cases the outcomes they described were tangible instances of changes in children's behavior. In other cases, the descriptions seemed to suggest expected changes that had yet to be actualized.

> I loved the enthusiasm that they felt and there was a lot of self-discovery even though it was directed, it was self-discovery on their part, and I think they felt,

> "wow, I'm really smart, I figured this out"…. it helped me realize how important it is that I take that type of teaching back to the classroom. [Deborah, 3rd, 15 years]
>
> They will use the science vocabulary… they will actually use it and talk about it and it's throughout the year. So the concepts aren't just for that one unit and then it's gone, they still talk about the different cloud types and they have a good understanding of what's happening when it's raining. They understand the concepts – the water cycle – and they can talk about it. They are just really looking deeper at everything around them and not just taking for granted – they're starting to really understand how things work in the world…. [Michelle, 1st, 4 years]
>
> …not only it inspired kids via science, it inspires kids to go to college. As we're walking around campus or looking at the library or looking at the buildings we're seeing college kids talking and laughing and joking. I can't tell you how many conversations not only about the science of it but about college – kids are excited to go to college [Misty, 5th, 15 years]

In even more concrete terms, participants discussed specific changes in their own teaching that they ascribed to the PLCs. The changes they described suggest a concerted effort to move from a kind of textbook-centered, didactic form of instruction to a more open-ended, inquiry-style of teaching.

> …we have science books but the science books don't come alive off the page unless you do some cool station experiment lesson that's hands-on that the kids can get dirty with and then it comes alive and they enjoy it and they get it. [Misty, 5th, 15 years]
>
> We do a lot more science in small groups….I think just using science in small groups has been something that we've done more that we didn't do before. It seems like before it was whole group, use your textbook, read the textbook together – that kind of thing. We found it very effective to break them up into small groups and have different stations of rocks so they can rotate through it. [Jenna, 2nd, 4 years]
>
> I'd say my pedagogy has changed a bit – trying to use more of a discovery learning for science. Y'know not just starting them out with the ideas or the concept that I want them to get but allowing them to discover through the experiment – coming to their own conclusion about what's happening and why it's happening; so in that way that part has changed. [Michelle, 1st, 4 years]

Limitations and Discussion

The most important finding of this study is that a group of elementary school teachers with demonstrably low self-efficacy in science teaching grew substantially over a period of 3 years as a result of their participation in a PLC. This growth was reflected in significant improvement of TSI scores, and in reported changes in classroom teaching practices and children's behavior.

Nonetheless, the study had several limitations and caution should be taken that the findings not be over-generalized. Most important are: the relatively small sample size (n = 55 in the experimental group); the somewhat atypical composition of the teacher and student populations (experienced teachers and a large proportion of ELL students); the inability to randomly assign treatments to experimental groups; the absence of classroom observation data, and the reliance on self-report measures of self-efficacy. We recognize each of these issues as a potential source of error and suggest that follow-up studies focus on mitigating them.

Despite these limitations, the findings provide strong support for many predictions emerging from Bandura's Social Learning Theory, including the dimensions and sources of self-efficacy. Perhaps most importantly, the results suggest that deficiencies in high school and college preparation can be overcome by high quality in-service programs for teachers.

Interviews with participants suggest that PLCs are a powerful vehicle that provide teachers with opportunities: (1) to collaborate with colleagues in small, grade-level groups; (2) to try out their ideas on children in their own classes; (3) to observe undergraduate interns interacting with children, and (4) to experience the outcomes of their work on children's behavior. Each of these components is strongly supported in Bandura's (1977, 1982) work and in the design and implementation of "best practices" in professional development programs (Loucks-Horsely et al. 2003).

The biweekly, grade-level meetings offer a forum for professional sharing that is typically absent in the elementary school environment. For many teachers, these meetings present a unique opportunity to immerse themselves in the essential work of the teaching profession; a chance to engage with colleagues in the intellectually demanding and emotionally rewarding tasks that build cohesion and confidence. They also provide a space for exploring potentially "risky" ideas (e.g. small groups; inquiry-style investigations) and for the social persuasion often needed to convince reluctant participants.

Much has been said about the isolation of the elementary teaching profession, and the failure of state and local governments to support professional activities such as travel to state and national meetings. PLCs offer a less costly and perhaps equally productive way of engaging teachers in the kind of practice-based, action research that helps build a community of local scholars (Bilica 2007). By supporting teacher research, PLCs enable teachers to develop testable predictions based on their own classroom experience and, in so doing, to enhance their own understanding of the nature of science.

The opportunity to test and confirm or restructure their ideas in the non-threatening environment of their own classroom provides a kind of direct, mastery experience that cannot be duplicated in other ways. In so doing, teachers are given an opportunity to implement a consensually-agreed-upon course of action and to observe and reflect on the results of their work.

Observing undergraduate teaching interns as they engage children in a newly designed lesson provides a very powerful vicarious experience. The roots of the Demonstration Laboratory can be traced to the original work of John Dewey (1902), however the importance of this kind of practical work seems to have been lost along with many of his "Progressive" ideas. Nonetheless, the comments offered by many teachers speak to the strong impact of these experiences on their confidence and sense of validation.

Finally, it appears that teachers in our study were strongly convinced that their work in the PLCs had some very positive effects on the children they teach. Several teachers commented on their children's growing vocabulary; their understanding of complex scientific concepts; their greater awareness of natural phenomena, and even their intention to attend college. These enhanced "outcome expectancies" contributed even further to the teachers' overall sense of self-efficacy.

Policy Implications

The study we have conducted provides strong support for the PLC as a powerful model of professional development in elementary science teaching. However to realize its full potential, the PLC will need much more support from policy-makers and administrators, and from industry, government and higher education. We concur with Fulton and Britton (2011), who argue that meeting the goals of PLCs will require major policy decisions including: (1) school staffing policies that provide teachers with the time, space and incentives to take on expanded professional roles; (2) enhanced participation by school principals; (3) implementation of online networking capacity, and (4) further, more in-depth, research on ways PLCs can be used to improve teaching effectiveness and student learning.

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