Curriculum is Not Enough: The Educational Theory and Research Foundation of the Exploring Computer Science Professional Development Model

Joanna Goode
University of Oregon
Education Studies
Eugene, OR 97403-5277
541-346-2826
goodej@uoregon.edu

Jane Margolis
UCLA
Graduate School of Education & Information Studies
Los Angeles, CA 90095-1521
310-794-4481
margolis@ucla.edu

Gail Chapman
UCLA
Graduate School of Education & Information Studies
Los Angeles, CA 90095-1521
310-794-4481
chapgail@gmail.com

ABSTRACT

In recent years, the computer science education community has shown strong commitment to broadening participation in computing in K-12 classrooms. Educational research highlights the critical role of professional development in supporting teachers to attract and effectively teach underrepresented students in computing. In this paper we present the Exploring Computer Science (ECS) professional development model and the research on which it is based. We also present findings about the impact of ECS professional development on teachers' practice. As computing education initiatives become increasingly concerned with scaling up from a regional to a nationwide presence, it is important to consider how the essential components of effective professional development can drive this reform.

Categories and Subject Descriptors

K.3.2 [**Computers and Education**]: Computer and Information Science Education – *computer science education, curriculum.*

General Terms

Human Factors

Keywords

Professional Development, Inquiry, Pedagogy, Learning Theory, CS Reform, Gender and Ethnicity, Broadening Participation in Computing

1. INTRODUCTION

As the computer science (CS) education community commits to broadening participation in computing, we must remember that access to courses and curriculum is not enough. While the courses, curriculum content, lessons, and activities are the critical framework, it is the teacher practice, pedagogy, and classroom norms that bring purpose and engagement to student learning. For this reason, CS teacher professional development (PD) is critically important, and its components must be understood.

In this paper, we will focus on the major activities enacted in the Exploring Computer Science (ECS) PD program, as well as the learning theory and research behind this PD model. We will also present current findings about the impact of the ECS PD experience on teachers' practice.

2. EXPLORING COMPUTER SCIENCE PROGRAM

Exploring Computer Science is an educational reform program built to address the lack of computer science curriculum, engaging pedagogy, and institutional support available for schools serving high numbers of students of color. It was designed in direct response to the issues surfaced through the research presented in *Stuck in the Shallow End* [16]. ECS is a yearlong high school computer science curriculum, and has now been adopted in several major urban districts nationwide. The ECS curriculum includes lessons for six units over the course of a year: 1) Human Computer Interaction; 2) Problem Solving; 3) Web Design; 4) Introduction to Programming; 5) Computing and Data Analysis; and 6) Robotics [12].

The core of the Exploring Computer Science curriculum highlights the problem solving, computational practices, and modes of inquiry associated with doing computer science, rather than just a narrow focus on coding, navigating particular syntax or tools.

Very importantly, ECS is a *program* that includes the ECS curriculum *in combination* with ECS teacher professional development. Our experiences with observations in classrooms and interviews with teachers show the complexities of teaching for broadening participation in computing, and that simply adopting the curriculum without sustained professional preparation is insufficient to develop the particular pedagogical strategies and classroom norms that must accompany the ECS curriculum.

3. ECS PROFESSIONAL DEVELOPMENT: CENTRAL FEATURES

The ECS PD is designed around five key activities, each of which is summarized in this following section. Though the PD is designed to support learning in ECS classrooms, the instructional features described are not curriculum or content specific. These same instructional experiences can be used to support the

SIGCSE '14, March 05 - 08 2014, Atlanta, GA, USA

ACM 978-1-4503-2605-6/14/03…$15.00.
http://dx.doi.org/10.1145/2538862.2538948

development of inquiry-based teaching practices across courses, including the forthcoming AP Computer Science Principles course.

What tie all of these activities together are the three pillars of the ECS program: CS content, inquiry and equity. The activities and teaching philosophy emanate from a body of research on successful teaching and learning [4,7,9,18]. ECS PDs are spaces of *active, participatory, creative, and engaged learning,* modeling what should occur in the classroom. Participating teachers are committed to teach the ECS curriculum.

3.1 Immersion into Inquiry

Exploring Computer Science PDs are filled with activity, collaboration, and reflection. There is often a lot of noise, as small groups of teachers and then the whole group are engaging in lesson planning, collaborating about how to solve the challenges they just encountered, and then reflecting on their own experiences teaching a lesson. From the very first hour teachers realize that this is not a passive, and unfortunately more typical, PD; instead ECS PDs are purposefully structured so that every teacher is participating, actively learning, and engaged.

This last point is very important. Too often PDs –across many subject areas---are passive events with teachers being *talked at*. And in computer science learning environments, too often a small group of participants who feel they know the most dominate all the discussions. The purposeful intention of the ECS PD, in contrast, is to create an equitable learning environment, where everyone is participating actively, establishing a community learning norm in which process and thinking is much more important than specific outcome or "correct" answers, and everyone recognizes that they have something to contribute.

ECS PDs open with a brief icebreaker to allow teachers to introduce themselves and the schools they represent. Immediately following, participants are immersed in the first inquiry activity. Professional development leaders model an introductory lesson from the ECS curriculum. This modeling typically includes: placing teachers in cooperative groups that offer diverse experience and knowledge in each group; a short journal prompt asking each participant to write about their understandings of a particular computing topic and how it relates to their lives along with a short debrief; as groups are engaged in a task facilitators roam the room, distributing necessary resources to each group and asking guiding questions to help groups move forward with their inquiry.

Beginning with a lesson that everyone can participate in is very important. For example, exploring the question "What is a computer?" teachers begin by counting the computers in the room. Teachers then share ideas in their small groups: Is an iPhone a computer? A digital watch? A thermostat? A light switch?

Following, the facilitators then bring the groups together to discuss their findings and reflections on their process. Then, as a whole group, the professional developers facilitate the dialogue as it moves from teachers reflecting on the particular activity as a learner, to the instructional implications about teaching this activity to urban high school students.

Therefore, within the first hour of the ECS PD, participants not only engage with computer science content, but they have an immersive inquiry experience that allows them to view computer science learning from the role of a student. An essential part of this activity, however, is the final whole-group debrief where the facilitators make the inquiry-based instruction explicit – including activity preparation, resources, journal prompts, scaffolding, guiding questions, drawing from student experience, cooperative group setup, facilitator interaction, etc. – and highlight inquiry strategies teachers need to use in their classrooms. Further, this debrief focuses on teaching practices appropriate for *all* students. In addition, asking participants to reflect on group dynamics and their overall experiences as learners in this activity typically then makes visible how gender, preparatory privilege, and other equity considerations materialize in computer science classrooms.

3.2 Teacher-Learner-Observer Model

Following this immersive modeling of an ECS lesson, the participants are then introduced to the primary set of activities for the duration of the PD week: *Teacher-Learner-Observer lessons*. Each small group is assigned one lesson from the introductory units of ECS that they will plan together and co-teach to the rest of the PD participants. Though the curriculum instructional guide already contains the framework of the lesson, it is up to the teachers together to "make music" with the notes on the page.

For the remainder of the weeklong PD, each group takes turns teaching key assigned lessons, chosen because they offer central CS concepts or have historically been challenging for ECS teachers. The content addressed in these lessons includes binary numbers, algorithms, searching and sorting algorithms, networked graphs, and data visualization and analysis.

The PD is structured so one group of teachers teach the lesson, most of the other participants engage in the activity as students, and the PD facilitators act as silent observers, noting the engaging and learning of participants during the lesson. After the activity, the debrief begins with the group of co-teachers reflecting on the effectiveness of the lesson, then the learners reflecting on their experience with the lesson, and finally, the observers noting what they saw during the sample lesson. Then the conversation is opened up, once again, to talk about the implications for teaching this lesson through inquiry for diverse high school students. After each lesson, groups that have not yet presented have short periods of time to meet and modify their lesson as necessary, to draw on the now prior knowledge of the participants. Thus, the cycle of the activity is (re)planning->teaching->reflecting.

This signifying ECS activity is based on the premise that teachers learn best about a common curriculum by teaching it and reflecting on it. As Loucks-Horsley and colleagues [15] note, "demonstration lessons can provide opportunities for teachers to enhance their content knowledge, practice their instructional approaches, and collaborate with other teachers as they implement the curriculum over time" (p. 248).

3.3 Professional Learning Community

The extensive and ongoing face-to-face interaction of the ECS PD model fosters a powerful professional learning community in which teachers learn from one another, support and share strategies for strengthening their teaching. Research by McLaughlin and Talbert shows how strong professional cultures are essential to changing norms of practice and pedagogy [17]. In the ECS Teacher-Learner-Observer model, each teacher recognizes the challenges associated with teaching a lesson to peers with the knowledge that the lesson will be analyzed and debriefed. Creating this space for reflection and observation presents an opportunity for teachers to work in a space of professional vulnerability and honesty. One ECS teacher reflected this way on the support of the ECS community:

> [ECS] *PD's have been extremely helpful to keep up to date and share and learn from other colleagues. The ECS PD's has helped me be part of a network of teachers that share similar concepts and practices. It is nice to talk to people that can share the same teaching area and understand each other.*

This space also serves to distribute wisdom of practice as well as a forum for developing teacher leadership in future PD or curricular endeavors.

3.4 Equitable Practices

Equity serves as a central guiding theme and component to the ECS PD. Equitable practices are both woven throughout and modeled during the PD institute. Research-based practices are specifically identified at each debrief: from structuring activities so that all students are actively learning, collaborating, and engaged: validating student ideas; drawing on students' cultural knowledge; using visuals to aid English language learners, modifications for students with special needs; and very importantly, deliberate scaffolding of the curriculum so that all students, from novices to more experienced students, are able to participate and feel that they belong in the class [5,6,13].

Beyond learning about instructional practices that address equity concerns, the ECS PD directly addresses teacher belief systems about who can (or cannot) excel in computer science classrooms. Drawing from central themes presented in *Stuck in the Shallow End* [16], teachers jigsaw the reading about computer science education in three ethnically diverse high schools in Los Angeles. After discussing the structural and psychological issues of access and equity presented in the book, particularly along lines of race and socioeconomics, participants discuss the notions of *deficit thinking* and *preparatory privilege* to deconstruct the relationship between opportunity and ability. When this conversation is revisited several days later after teachers have time to reflect on the readings and discussion and connect those with the ECS lessons that are taught during the week, often the equity issues become deeper, more concrete, and more personal. As one teacher reflected on his teaching practice after these discussions:

> *I must not take current level of interest and current level of knowledge [of students] as the only (or even a very good) indicator of future success in computer science. I have had experiences teaching Algebra 1 that I can think back to--kids who came in hating it, learning to love it, and then even choosing to study math. I will have to be very open to the possibility of the same kinds of stories in my computer science classes.*

Allowing for this period of time for teachers to absorb and process computer science equity issues elevates both the lesson debriefing discussions and more formalized discussions around *Stuck in the Shallow End* as it is reexamined later in the week.

3.5 Professional Development Into the Classroom and Throughout the Year

Acknowledging that teacher learning is dynamic and takes place over time, a central premise of the ECS PD model is the establishment of a long-term relationship between the teachers themselves and with PD providers. Rather than presenting PD as a one-stop drive-by event, a culture of ongoing community learning and reflection is established amongst the participants. The ECS PD activities mentioned above are first implemented in a one-week summer institute, then reinforced and built upon in subsequent gatherings. Quarterly follow-up PD sessions, followed by a second summer's institute, provides space to reflect and acknowledge the notion that much of teacher learning takes place in their own classrooms. The on-going PDs provide opportunities for teachers to continue working with the content, pedagogy, reflection about student work and learning assessment. Recognizing the research that finds how teacher learning as a process, rather than a discrete event in an off-campus location, is an essential element of the ECS PD design [15].

4. RESEARCH FOUNDATION OF ECS PD: WHAT WE KNOW ABOUT TEACHING

These above activities of an ECS PD are designed in response to educational research on effective teaching and learning. In her review of research on teaching and learning, educational scholar Darling-Hammond [9] notes that studies across disciplinary domains find that highly effective teachers support the process of meaningful learning by:

- Creating *ambitious and meaningful tasks* that reflect how knowledge is used in the field;
- Engaging students in *active learning*, so that they apply and test what they know;
- Drawing *connections to students' prior knowledge* and experiences;
- Diagnosing student understanding in order to *scaffold the learning process* step by step;
- *Assessing student learning continuously* and adapting teaching to student needs;
- Providing *clear standards*, *constant feedback*, and opportunities for work;
- Encouraging *strategic and metacognitive thinking*, so that students can learn to evaluate and guide their own teaching (p. 5).

It is these tenets of effective teaching that get folded into and modeled in our ECS PD activities. Darling-Hammond and colleagues point out that connecting these principles with particular teaching strategies differs depending on a sophisticated understanding of the content, the learner, and the goals of instruction [10]. *Pedagogical content knowledge* is a term offered to capture the particular pedagogical techniques that are appropriate for designing meaningful tasks, addressing common misconceptions, and engaging in ongoing, formative assessment of student learning within a particular discipline [3]. For our ECS PD model, we have taken these educational research findings and apply them for CS pedagogical content knowledge.

5. INQUIRY-BASED TEACHING AND LEARNING

5.1. Defining Inquiry-Based Approaches

Exploring Computer Science is based on an inquiry-instruction approach to learning. The family of approaches that can be considered inquiry-based includes project-based learning, problem-based learning, and design-based learning [4]. Though each approach has its own unique characteristics, they all share a common premise that students should be actively engaged in building their own learning through meaningful long-term learning experiences. Learning scientists and educational researchers point to a set of studies that conclude students learn more deeply and perform better on complex tasks if they have the opportunity to engage in more authentic learning [9]. Rather than learn within a constrained and disconnected context, this authentic learning approach encourages students to connect real world problems to the subject matter at hand. Research has shown that students who learn subject matter through an inquiry-based approach demonstrate increased performance on intellectually challenging performance tasks when compared to their direct-instruction peers. Inquiry-based learning also leads to significant gains in problem-solving abilities, curiosity, creativity, independence, and positive feelings about school [4].

Further, educators note that engaging students in the context of complex, meaningful projects that require sustained engagement, critical thinking, collaboration, management, communication, and management of resources to develop final products or presentations builds the types of 21st century skills advocated by new sets of national standards.

5.2 Inquiry-based Learning Requires Structure

Successfully enacting an inquiry-based approach to teaching requires extensive pedagogical content knowledge and understanding of student culture to create, facilitate, and assess the opportunities that activate learning for students. Inquiry requires well-designed and carefully planned classroom practices in order for students to have the necessary opportunities to make connections between key concepts across a discipline. Otherwise, the activity can fall into unstructured chaos with no purpose or clear understanding of curricular meaning of the activity at hand.

The same caution is true about cooperative small group learning, a key strategy of inquiry-based instruction. Though initially conceived of by social psychologists to help seed interpersonal friendships across races following desegregation [2], small groups of students working together showed instructional benefits, too. Cohen defines cooperative grouping as "students working together in a group small enough that everyone can participate on a collective task that has been clearly assigned" [8]. Studies overwhelmingly show that there are significant learning benefits for students working on activities in small groups as opposed to activities when students work individually [4,14]. Even on later individual assessments, students working in cooperative groups outperform students who learned the same material individually. But as with any element of inquiry, providing explicit structure to the cooperative learning activity is necessary to avoid devolving into lost instructional time. The teacher's role in facilitating the assignment of group roles, collaboration-worthy tasks, modes of communication, facilitating discussions through critical thinking and questioning, and individual accountability in group settings are essential elements for thriving cooperative groups.

Many domain experts may take exception to an inquiry-based model and note that they themselves learn effectively with direct instruction. This view is not necessarily at odds with inquiry-based learning. Studies show that lectures can be effective for people who have previously engaged in an activity and have an established understanding of the conceptual connections within a domain. But, sole direct instruction does not seem to bolster student learning as does the incorporation of inquiry [9].

6. RESEARCH ON STEM PROFESSIONAL DEVELOPMENT

As noted earlier in the article, settings of PD are sites of learning and teaching, highlighting the need for well-designed PD experiences that model and build the types of inquiry-based instruction encouraged for the classroom. PD is most effective when it is not in isolation, but rather, rooted in the realities of what teachers can implement in their classrooms. Disparities between PD and what teachers can do in their classroom decrease the effectiveness of the PD. In a nationwide survey, teachers reported that their knowledge and skills grew and their practice changed when they received PD that was coherent, *aligned with curriculum, focused on content knowledge, and involved active learning* [11].

This type of PD requires sustained periods of time. Two studies demonstrated that teachers who attended 80 or more hours of PD in inquiry-based science during the previous year were more likely to use this instructional method than teachers who attended fewer hours [11]. Another study examining the correlation between sustained PD and student achievement found that the largest positive effects were for programs offering between 30-100 hours and spread out over 6-12 months. This large-scale study also found that PDs that are based on active learning, include content knowledge, and have a strong coherence to broader teaching context develops teacher knowledge and skills, which in turn leads to substantial changes in teaching practice. Clearly, this research demonstrates that the "drive-by workshop" approach to transformative PD is not sufficient for transforming teaching practices.

In *Designing Professional Development for Teachers of Science and Mathematics* [15], Loucks-Horsley and colleagues suggest that it is fruitful to examine PD as a dynamic decision-making process, rather than as a static set of models. They propose that first articulating a common vision for the PD, then understanding the unique resources and conditions facing the local site, and finally identifying critical issues to be aware of should be done before designing particular strategies or experiences to enhance teacher learning and practice. This is an iterative process that acknowledges evolving needs, so each design cycle is followed by reflection and revision by the professional developers.

In their review of effective teaching, learning, and PD in STEM disciplines, Loucks-Horsley and colleagues identify the following features of effective PD:

- PD must have students and student learning at the core of the PD, where all students are considered so that issues of equity and access are addressed from the beginning.
- PD should include the active involvement of those with experience in teaching the subject-area successfully in high school: those who understand teaching, pedagogy, and pedagogical content knowledge.
- PD must be focused on pedagogical content knowledge, but reinforce and leverage knowledge that teachers already have; it should be designed so that teachers with different backgrounds and abilities can succeed and flourish.
- PD takes time. Because of the focus on pedagogy and teaching, face-to-face meetings with PD participants are essential, and should not be devoted solely to disseminating content.
- PD should be designed to nurture leaders so that participants see a path to professional growth as well as development.
- PD should help build communities of learners and build them locally when possible. This requires an understanding of local issues, constraints, and opportunities.

These are part of the guiding principles of our ECS PD model.

7. RESEARCH ON ECS PD IMPACT

Below we present a research analysis of teacher reflections about their ECS PD experience and the connections they see between their PD experiences and changes in their teaching practice. These reflections were gathered through end-of-year teacher surveys, teacher interviews, and PD evaluations. We also have conducted a full year of extensive classroom observations. These teacher reflections have been "triangulated" with our analysis of classroom observations and interviews that we are currently finalizing.

7.1 Research Process

During the 2012-13 school year, 31 LAUSD ECS teachers actively participated in the ECS program across 25 schools in Los Angeles County. They taught between one to four ECS classes each for a total of approximately 57 classes, over 2000 students. The majority of students qualify for “free and reduced lunch,” (an indicator of low-income poverty levels) and the 2012-13 ECS student enrollment demographics are 45% females, 81% Latino, and 6% African American. These percentages closely mirror the District population demographics.

Of these, 23 teachers completed at least some portion of an end-of year survey. Participants range from first year ECS teachers to those with four years of experience teaching ECS. All of the participants are LAUSD teachers, except for one who is now working in another school district within the county.

7.2 Perceived Utility of ECS PD

As shown in Table 1, 91% of the teacher respondents categorized the ECS PD sessions as very useful (74%) or useful (17%). Teachers also rated the value of the ECS community, specifically networking with colleagues, as very useful (65%) and useful (26%).

Table 1. Teachers’ perceived utility of ECS activities (n=22)

	Not useful at all # (%)	Somewhat useful	Useful	Very useful
ECS PD sessions	0	1 (4%)	4 (17%)	17 (74%)
Networking with colleagues	0	1 (4%)	6 (26%)	15 (65%)

7.3 Teacher Changes in Practice

On the end-of-year survey, teachers were asked to share what first came to mind when asked how they have changed, if at all, in their practice after participating in ECS. Almost all respondents agreed or agreed strongly with the statement – *I have become more skilled in using inquiry-based strategies by participating in ECS.* An example of a teachers’ elaboration of this is:

> *Having faith in my students ability, not volunteering the answer, and empowering my students to trust their reasoning and unique way of solving problems is the major change in my teaching.*

Teachers also shared their new understanding of the connection between the curriculum, pedagogy, and equitable teaching practices. One teacher wrote:

> *This [ECS PD] also made me reexamine how I teach my classes. The course begins with activities that are accessible to all yet build the necessary CS concepts. The activities gave students a way to learn and at the same time get over crippling ideas that they cannot be successful in studying CS.*

Another teacher reflected further on the ties between equity and inquiry teaching practices*:*

> *My thinking has changed tremendously towards “equity in CS.” I used to think by just providing the proper equipment, classroom, textbooks, lesson material, lecturing, available at off hours and having students work independently I was providing plenty of equity. After this workshop, I realized I really never provided equity to ALL students. Today my thinking has changed, I saw collaboration in action and it can really work, my outlook has changed towards the concept and I will be actively participating, planning and promoting. I have a lot of work to do by learning to be a good facilitator and begin practicing on my inquiry techniques.*

All except two agreed or agreed strongly with the statement – *I know more about computer science concepts as a result of participating in ECS.* This is very important finding as we recognize the challenge teachers face in teaching a new curriculum and particularly new content. In ECS PD’s, CS content is happening all the time, in the context of learning and working with inquiry and equitable teaching practices.

Teachers also wrote about gaining confidence in their teaching, gaining knowledge and skill in particular aspects of the CS curriculum and getting a better sense of the “big picture.” Accompanying their own gain in confidence was a gain in confidence in their students’ ability to tackle problems. As shown in Table 2, all but one teacher felt that the ECS PD had a large and/or some impact on their teaching of the three pillars of ECS (CS content, inquiry and equity).

Table 2. Perceived impact of ECS program on practice

	Not sure	No impact	Some impact	Large impact
Inquiry-based instruction	0	1 (4%)	9 (39%)	11 (48%)
CS content knowledge	0	1(4%)	8 (35%)	13 (57%)
Equity-based instruction	0	1 (4%)	11 (48%)	9 (39%)

ECS teacher Leslie Aaronson, in her personal blog describes her own change of practice that was prompted by working in the ECS program [1]. Beginning with the opening line “ I have a secret” Aronson reveals that she is “no longer the most knowledgeable person in her classroom.” She then explains:

> *My confidence in inquiry grew this past year when I started teaching Exploring Computer Science which stresses inquiry as one of the three major components of teaching the curriculum. It is also stressed when I go to professional developments about developing critical thinking and using project based learning. I have found that now that I don't*

easily have the answers I am much stronger at asking questions in order to get the students to think and begin to ask more questions on their own.

Maybe that is my secret.

Now, instead of feeling insecure when I don't know something, I celebrate the thinking and inquiry coming from the students. "Yes, that is a good question," I respond. "How can you find out the answer? Where would you look? What keywords would you use to research it? Have you asked other people in the room if they have found a solution?" Now they are learning to trust themselves to find the answers. They know that questions are great and solutions are there for them to figure out on their own. And that is what I call successful learning.

In fact, it is the teaching of CS content through these inquiry and equity practices that engage students with the real learning of computer science.

8. CONCLUSION

Because our ECS curriculum is more than "notes on a page," and is integrally linked to inquiry instruction and commitment to equitable practices, we have committed to partnering with and supporting projects that have adopted the ECS program---*both* curriculum and PD model. The traditional curriculum and methods of teaching computer science have left too many students feeling that computer science is "not for me." As a community we must learn from the extensive body of educational research about teaching, learning, and PD planning. Broadening participation in computing will require CS teacher professional learning communities, and teachers who focus intensely on new forms of pedagogy and classroom norms.

By developing this ECS computer science teacher PD and learning community model, we are working to deepen and strengthen the national high school college preparatory infrastructure for computer science education and broadening participation in computing. But, we believe that the importance of our work extends beyond computer science. In line with this year's SIGCSE theme, "Leveraging Computing to Change Education", the issues we address are at the center of our country's educational crisis: what is effective teaching, how to deepen students' critical thinking, what is the importance of PD, what is the research behind effective models, and very importantly, how do we broaden participation and engagement in computing and in all of education.

9. ACKNOWLEDGEMENTS

We acknowledge the contributions of our evaluation team from UCLA CRESST, specifically Christine Ong and Kevin Binning. We also gratefully acknowledge the "Broadening Participation in Computing" program of the National Science Foundation for funding this research.

10. REFERENCES

[1] Aaronson, L. 2013. *You don't need to be an expert*. Weblog. Retrieved September 1, 2013 from http://leslieaaronson.weebly.com/1/category/all/1.html

[2] Aronson, E. and Bridgeman, D. 1979. Jigsaw groups and the desegregated classroom: In pursuit of common goals. *Personality and Social Psychology Bulletin*, 5, 4, 438-466.

[3] Ball, D. L. 1993. With an Eye on the Mathematical Horizon: Dilemmas of Teaching Elementary School Mathematics. *The Elementary School Journal*, 93, 4, 373-397.

[4] Barron, B. and Darling-Hammond, L. 2008. *Teaching for meaningful learning*. Jossey Bass, San Francisco, CA.

[5] Barton, A. C. and Tan, E. 2010. We be burnin'! Agency, identity, and science learning. *The Journal of the Learning Sciences*, 19, 2, 187-229.

[6] Boaler, J. 2008. Creating mathematical futures through an equitable teaching approach. *Teachers College Press*, 33, 4, 239-258.

[7] Bransford, J., Brown, A. L. and Cocking, R. R. 1999. *How people learn: Brain, mind, experience, and school*. National Academy Press, Washington, D.C.

[8] Cohen, E. G. Restructuring the classroom: Conditions for productive small groups. 1994. *Review of Educational Research*, 64, 1-35.

[9] Darling-Hammond, L. 2008. *Powerful learning: What we know about teaching for understanding*. Jossey-Bass, San Francisco, CA.

[10] Darling-Hammond, L. and Bransford, J. 2007. *Preparing teachers for a changing world: What teachers should learn and be able to do*. Jossey-Bass, San Francisco, CA.

[11] Darling-Hammond, L. and Richardson, N. 2009. Teacher learning: What matters. *Educational Leadership*, 66, 5, 46-53.

[12] Goode, J. and Chapman, G. 2008. *Exploring computer science*. Computer Science Equity Alliance, Los Angeles, CA.

[13] Howard, T. 2010. *Why race and culture matter in schools.* Teachers College Press, NY.

[14] Johnson, D. W. and Johnson, R. T. 1989. *Cooperation and competition: Theory and research*. Interaction Book Company, Edina, MN.

[15] Loucks-Horsley, S., Stiles, K. E., Mundry, S., Love, N. and Hewson, P. W. 2010. *Designing professional development for teachers of science and mathematics*. Corwin Pr, Thousand Oaks, CA.

[16] Margolis, J., Estrella, R., Goode, J., Holme, J. J. and Nao, K. 2008. *Stuck in the shallow end: Education, race, and computing*. MIT Press, Cambridge, MA.

[17] McLaughlin, M. W. and Talbert, J. E. 2001. *Professional communities and the work of high school teaching*. University of Chicago Press, Chicago, IL.

[18] National Research Council. 2000. *Inquiry and the National Science Education Standards: A guide for teaching and learning*. National Academies Press, Washington, DC.

[19] Stein, M. K., Smith, M. S. and Silver, E. A. 1999. The development of professional developers: Learning to assist teachers in new settings in new ways. *Harvard Educational Review*, 69, 3, 237-270.

[20] Yoon, K. S., Duncan, T., Lee, S. W. Y., Scarloss, B. and Shapley, K. L. 2007. *Reviewing the evidence on how teacher professional development affects student achievement.* Institution of Education Sciences, Washington, DC.