PROBLEM-BASED LEARNING APPROACH FOR SCIENCE TEACHERS' PROFESSIONAL DEVELOPMENT

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Background

The Center for Craniofacial Molecular Biology (CCMB)—a research laboratory of the School of Dentistry at the University of Southern California—was announced as a site in 1990 for the California Science Project (CSP), a sub-division of the California Subject Matter Projects[1]. In 1991, the Center to Advance Pre-college Science Education (CAPSE) was funded by the National Science Foundation and also based at CCMB. The mission of CAPSE was to transform pre-college science education for children in the South Central and Eastside areas of Los Angeles with a large majority of minority and historically under-served populations. The goal was to improve science education through teacher training, thereby increasing the possibility of underrepresented minorities entering the scientific pipeline and pursuing careers in science.

Challenge

The USC-CSP formed a strong partnership with the Los Angeles Unified School District (LAUSD). In the past two years, the urban systemic initiative in LAUSD—Los Angeles Systemic Initiative (LA-SI)—challenged the USC-CSP to establish a cluster[2]-wide science education initiative to improve students' academic performance. The achievement will be enhanced through teachers within the cluster teaching inquiry-based and standards-based science.

Wheatley (1994) states that the current standards-based reform movement has brought to light a new instructional leadership that is guided by evidence. Thompson, Wang and Shuler

(1998) state that an evidence-based quality instruction is contingent on a variety of factors, such as articulation strategies, instructional resources, and a wealth of pedagogical knowledge. The challenge we faced is three-folded: First, the coordination of science education between different grade levels and different schools represents an organization challenge even in small school districts. In major metropolitan districts like LAUSD, the lack of coordination can result in children entering middle schools and high schools with widely divergent science abilities. In addition, high students transition rate in LAUSD (in some LA areas, less than a half of the students are the same students who enrolled in the beginning of the semester) has forced the educators to look for effective strategies in school articulation. Second, similar to the other elementary teachers around the nation, the elementary teachers in Los Angeles devote so little instructional time in teaching science due to their insufficient preparation in science content training. Third, "inquiry" instruction to classroom teachers is often un-structured and has different meaning to different educators, thus most teachers resist an inquiry approach and still provide a traditional lecturing approach—students are hand-fed information.

Schmidt (1998) uses TIMSS findings to confirm the crucial role of educational standards in science teacher preparation and professional development. Accordingly, the lack of cohesive vision in the United States has caused students low performance in secondary schools. TIMSS findings echo the need for standards-based science education reform. Early on in the developmental stage of the cluster initiative, the USC-CSP faculty and teacher leaders[3] introduced the national science education standards to the teachers. The science educational standards are held as a tool for grade articulation. Moreover, a structured inquiry approach—Problem-Based Learning (PBL) was introduced to teachers as a model for practicing inquiry-based instruction. Through the PBL format, teachers worked with curators of science museums, scientists in research laboratories, and faculty in higher education to acquire science content knowledge.

During the past two years, the USC-CSP have connected various venues and formed partnerships with local science education centers and informal science education venues to take the challenge. Through a program evaluation (Wang, 1998a), the impact on student science achievement was found to correlate with the following program elements:

- introduction of content and experiences required to develop teacher-leaders who will assist in institutionalizing the science education programs
- providing extended pedagogy experience in inquiry-based science education
- focusing on the national science education standards as a foundation for structuring new initiatives for science education
- building the background science content of teachers
- initiating K-12 articulated cluster-wide programs of science education
- establishing partnerships with informal science education centers, school district, and faculty of the university to maximize the resources available to aid students and teachers
- developing programs for student assessment and program evaluation to determine the impact of the initiatives

Wang (1998a) further concluded that all the above features were crucial to the success of the USC-CSP science education initiatives. However, for the purpose of this paper, we want to focus our discussion around a key feature of USC-CSP—Problem-Based Learning (PBL)—as it has created a paradigm shift in our beliefs and efforts in teacher professional development.

Problem-Based Learning

Problem-Based Learning was introduced in medical education by a Canadian medical school in 1968 (Neufeld & Barrows, 1974), and has recently begun to attract growing interest among K-12 educators as an exemplary inquiry approach (Checkley, 1997; Glasgow, 1996; Jones, Rasmussen, & Moffitt, 1996a; Jones, Rasmussen, & Moffitt, 1996b). PBL as an instructional model demonstrates that any learning can be accomplished through “learning prompts,” which serve both to intrigue the learner and ensure high quality learning outcomes. PBL for inquiry learning has been widely reported as producing desired learning outcomes: students became responsible for their own learning, developed active inquiry habits, and learned effective research techniques (Albanese and Mitchell, 1993; Wang, 1998b). Inquiry-based instruction using the PBL approach has also produced significant improvements in student performance in multiple-choice examination (Shuler & Fincham, 1998). This distinguished PBL from other inquiry attempts that were criticized because they only enhanced students’ attitudes and process skills, but did not significantly improve their acquisition of content knowledge.

There are three key components of PBL that were introduced to teachers involved in our professional development programs: (1) learning cases, (2) student-centered learning, (3) small group learning (Wang, Thompson, & Shuler, 1998). The *learning cases* are the core of PBL. Cases need to have specific learning outcomes embedded. In our cases, these learning outcomes are carefully aligned with learning standards described in the national science education documents. The *student-centered learning* component of PBL transforms teachers into group learning facilitators who facilitate the students learning process. One example of a teacher’s task is to introduce to students various strategies to effectively utilize learning resources, another is to use questioning techniques to help stimulate student thinking. *Small group cooperative learning* in PBL means that students work within small groups, where they are responsible for both their peers' and their own learning. When learning needs are identified in a learning case, each member will take a small portion of the learning tasks and become "master[4]" of those tasks. It becomes their responsibility to share their findings with their peers. The responsibility of their peers is to expect and demand quality sharing in a scheduled group study session. Figure 1 is a flowchart that indicates the basic structure underlying this approach.

Insert Figure 1.

PBL for Teacher Professional Development

PBL was woven into the design of USC-CSP professional development institutes because of the belief that as the participants grew professionally in a PBL environment, they developed a deeper conceptual understanding of PBL and increased their confidence in using this type of an approach. In the summer 1997, 70 teachers participated in a two-week Summer Institute. During the Summer Institute the development of the problems used as vehicles for learning was directly tied to the national science education standards. Grade-specific content and performance standards were identified by each of the learning groups. These standards were used to generate problems that would facilitate student learning. Thus the standards-based science content became integrated into the learning objectives to be achieved in each problem making the standards essential to curricular development and K-12 articulation. Once the standards were identified and the problems were developed, teachers proceeded to identify specific instructional resources, including hands-on science kits, which would be necessary to complete the inquiry-based learning experience of the students. PBL inquiry allows teachers to achieve standards-based instruction through an inquiry process. The participating teachers created one PBL case per grade level in K though eight and one for grade nine to twelve. These cases were test-run on teacher participants and the outcomes used to modify the approach for greater effectiveness and correlation with the desired set of national content standards.

The teachers reported the test-run process helped them not only in understanding PBL, but also understanding the differences in science education objectives between grades. The process has effects on both horizontal and vertical grade instructional articulation. As teachers of the same grade worked together to prepare the learning cases, same grade teachers from different schools had the opportunity to communicate with each other and share their instructional objectives and come to an agreement based on the national standards documents. Furthermore, as teachers of different grades practiced and recognized what was expected in the learning cases crafted by other grade teachers, they also gained an awareness of their role in terms of the students' K to twelve education.

The Summer Institute participants applied these cases to their classrooms after the Summer Institute. The field observation (Wang, 1998a) information collected on the implementation of PBL showed strong evidence that elementary teachers, especially, increased instructional time spent on science lessons. Revised PBL cases were successful in positively affecting student attitudes toward science learning. Some advanced teachers even generated additional PBL cases for their own instructional objectives. Additional science content expertise, skills in integrating the instructional supplements such as science kits, and PBL pedagogy were regularly introduced during a "Wednesday at Westside" series for participating teachers as a way to provide continuous support.

In the summer 1998, the majority of participants from the previous year returned along with colleagues, so that Institute participation reached approximately one hundred. The USC-CSP teacher leaders designed eight PBL cases to provide the participants with an in-depth, adult-level inquiry experience. Prior to the Summer Institute, in a mini-institute held on April 28, 1998, approximately forty teachers were introduced to the PBL cases and used the PBL methodology to determine the necessary learning objectives to better understand the problem cases. This information shaped the planning of the inquiry-based investigations pursued by the teachers during the first week of the Summer Institute. The embedded content behind these eight cases is advanced science around the learning areas of archaeology, microbiology/ecology, molecular biology, marine mammal biology, marine plant biology, botany, and earth science. Every group brought back their research findings and prepared posters and presentations in the second week. Moreover, the second week was focused on classroom adaptation of the science content, development of a common grade level matrix for their cluster and articulation of science learning throughout the K-12 schools in the cluster. The classroom adaptations of the new material were focused on approaches necessary to achieve the science education standards and to identify opportunities for learning through overlaps between multiple educational disciplines (e.g., literature, art, social science). Teachers investigated hands-on applications for the classroom, explored instructional materials and discussed how they fit into the matrix. Grade level groups built a "living" matrix (Parade of the Rooms) using a classroom as their canvas so that as a culminating activity for the institute, all grade levels could visit and see what constituted "teaching and learning" at each grade level coordinated by the cluster project[5] framework. All classrooms and grades emphasized the applicability of teaching activities through the mastery of science standards by the students.

The 1998 Summer Institute participating teachers were also involved in various evaluation processes. Three different surveys (Group Learning Survey, Facilitator Effectiveness Survey, and Daily Reflective Journal) were collected from teachers. Selected teachers were also interviewed. In addition, the research presentations were videotaped for further analysis. Our preliminary findings from analyzing the data collected, found teachers from the previous year reported that the institute assisted them in gaining more in-depth understanding of issues involved in implementing the PBL in their own classroom[6]. New teachers reported a significant increase in confidence in applying PBL as an inquiry-based instructional approach. The participants reported they were highly motivated to acquire more knowledge in those eight science areas and also enriched their perceptions of scientific research methods.

In the summers of 1997 and 1998, the teachers we worked with had been exposed to a simple format of problem based learning. In an article written by a USC Chronicle reporter, who visited the 1998 Summer Institute, an extensive report about the USC-CSP professional development activity was reported, which has brought attention to both the USC campus and LAUSD schools.

Transfer of PBL to the K-12 Classrooms

In our previous discussion, we assumed that teachers will implement an alternative instruction if they were actually exposed to the alternative instruction directly. The PBL professional development has been reported as a great success. We continue to investigate how such success is being transferred to the K-12 classroom. In the field observation, we found all the teachers' classrooms share one common feature—science was presented in FACT, IDEAS, & LEARNING NEEDS sheets. In Appendix A, a field journal from our project evaluator has painted a vivid example of how PBL was applied to the elementary students by one of our USC-CSP teacher leaders.

Epilogue

Many successful PBL cases have been applied in LAUSD's elementary schools. Michael Blount, Moni Olguin, and Nettie Pena created a video to document how PBL can be applied to both English- and Spanish-speaking students in science learning. Together with Ginnene Branch, an elementary science teacher who has a Masters degree in art, they produced a PBL case—*Sex in the Garden*—to show to the class the substance carried by the pollinators of plants and the anatomy of flowers. In 1997, at the California Science Teacher Annual Conference, they brought the *Sex in the Garden* workshop to the science teachers of California. This course has been accepted for a short-course format at the 1999 National Science Teachers Association Convention and will be open to teachers of the nation. In addition, LaNelle Harvey, another elementary teacher who is currently pursuing her Masters degree in science education, has written several PBL cases for her fourth to sixth graders to learn earth sciences, physical sciences, and social sciences. Lastly, teachers of PBL provided evidence that this pedagogical approach helped student learning outcomes. Vicky Seabold has used PBL for two years as an instructional approach for her bilingual 4th graders. She uses various problem prompts initiated by her students. Her PBL approach successfully helped her students distinguish themselves in various learning assessments during the past two years. In 1997, for their excellent performance, these Martin Luther King Elementary Students were ranked fourth for their grade level district-wide on the Stanford Nine test. It is believed that such exciting implementation reports will continue as more LAUSD teachers are introduced to Problem-Based Learning.

Notes

1. The California Subject Matter Projects (CSMP) are a network of subject matter projects providing professional development for teachers of students in grades K-12. Established in 1988, pursuant to SB 1882, the Projects have recently experienced significant change with the passage of AB 1734 (Ch. 333, 1998). The major changes in direction is to devote more efforts to improve student achievemnt, especially in low-performing schools.

2. LAUSD was divided into 27 “clusters.” Each cluster constitutes one or two high schools and their feeder middle and elementary schools.

3. The seventeen USC-CSP teacher leaders are K-12 teachers from the LAUSD, some joined CAPSE institutes before others. They have been prepared and supported to provide professional services to other teachers in LAUSD. Most of them now are still classroom teachers and take heavy responsibility within their own schools as change-agents to assist the school transformation. The experiences we had in the preparation of this group have been documented and drawn dramatic attention from all the other sites of California Science Project.

4. Students will be asked to provide a brief presentation of their own research findings. Facilitators use multiple questioning strategies and a rubric of Learning Mastery Evaluation to assess and monitor student learning when students work with them.

5. The Venice/Westchester cluster developed a science project called Orchid Project in 1997.

6. The result from data analysis will be presented at the 1999 NARST Annual Conference at Boston.

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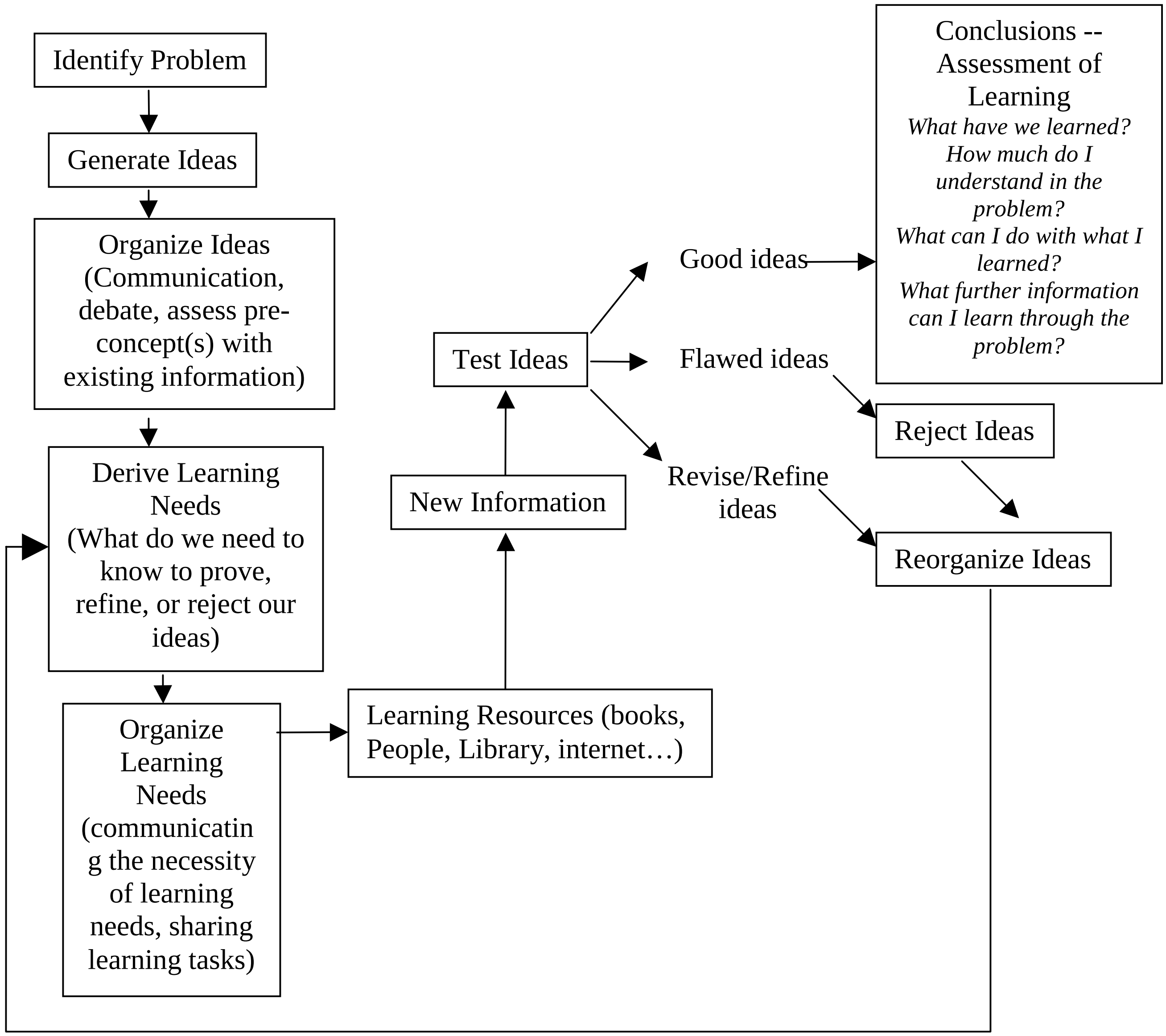
Figure 1.


Identify Problem
Generate Ideas
Organize Ideas (Communication, debate, assess pre-concept(s) with existing information)
Derive Learning Needs (What do we need to know to prove, refine, or reject our ideas)
Organize Learning Needs (communicating the necessity of learning needs, sharing learning tasks)
Learning Resources (books, People, Library, internet…)
New Information
Test Ideas
Good ideas
Flawed ideas
Revise/Refine ideas
Conclusions -- Assessment of Learning
What have we learned? How much do I understand in the problem? What can I do with what I learned? What further information can I learn through the problem?
Reject Ideas
Reorganize Ideas

Appendix A.

Field Observation Journal

November 4th, 1998

Today, Patt and I went to El Centro Elementary School to visit a teacher who is in our CSP Leadership Cohort. She teaches 4th and 5th graders (it's a mixed classroom). Ms. Washington started her two-hour lesson with a video showing a taped news report on the *Exxon-Valdez* oil spill event that happened years ago near Alaska. Her instruction to the students was to LISTEN carefully to the reporter. The tape was about 10 minutes long. I thought the kids might not comprehend the news and they might start to lose focus after 5 minutes at most. Because that's what happens to me; when the news is too long and there are so many vocabularies that I don't recognize or relate to my field. I started to drift away and turn my attention to observe the students instead.

These students, beyond my expectation, were so quiet and so focused. That amazed me! Then I thought they might just be shy in front of us, two visitors with a video camera. They probably think that "what if mom and dad see this tape at the next parenting conference…?"

Ms. Washington started to put a blank poster on the wall and asked the students "what did you see and hear from the news? What are the FACTS?" Over 2/3 of the thirty-five students raised their hands up in the air, wanting to share what they saw and heard. "My gosh, they were really paying attention to the tape," I thought to my self. After the FACT sheet was completed, Ms. Washington asked students "what is the problem here?" Almost synchronously the students said: "The oil spilled in the ocean."

Ms. Washington pulled out another blank poster and asked students "what are your ideas to our problem? Remember, there is no idea as a crazy idea, or weird idea; whatever idea you have is a good idea. Sometimes scientists will think of something totally bazaar and yet it leads to a great discovery." Again, students quickly helped her fill out the IDEAs poster.

At first, their ideas were so "out there" and I said to myself: "they are just nine or ten years old, what do you expect?" As time went by, one student inspired the others—he said: "we can freeze the oil and break it into pieces and take it out of the water," another student said "we can ask scientists what is the solution to break oil and make it less toxic" another student said "we should find out if we can make the oil sink to the ocean floor."   I thought to myself: "This is amazing, they are so creative and clever." The students quickly filled out two posters of ideas and they were great ideas!

Ms. Washington was so happy and she pulled out another blank poster and asked the class: "What do we think we need to learn to test our ideas? What tools do you need to test ideas?" Unlike the "silent moment" briefly presented at the previous idea generation process, students burst out with their learning needs one after another. The instrument, the tools, and the resources were listed on the board by these nine or ten year-olds in a short time.

Ms. Washington asked students to select a topic that they want to investigate and they formed into investigation groups. She then asked several students to bring in all the tools these students just listed. I was stunned, she had predicted what would come out from the students' discussions with only one or two items missed. What an incredible process!

Students started to be charged by their self-selected group tasks. Some of them worked right into their own investigations, some of them sat there for a long time not showing any eagerness to bring any tool to their tables. They sat there and looked around, then started to write things together and then decided their investigation plan. This group became hyper in their investigations. Of course there were students that simply had no clue about what is scientific process: they pulled all variables together and claimed, “we found it, we found the solution.” As Ms. Washington rushed to the table, they could not show her what they had just found. They failed to prove their claim. Ms. Washington asked them to add one variable at a time and record what happened when a new variable is added. They needed to write as they conducted their investigation. She told her students “think before you act, write in your journal why you did every step you did.”

At the end of the two hours, when all the students in the school heard the bell ring and all went screaming and rushing out of the school, guess what, Ms. Washington’s class was sitting seriously with their groupmates and listening to every other group’s presentation. They debriefed on what they have found so far in their own investigation. They stayed there for discussions and provided ideas to each other for another 30 minutes. “The school day is over” seems not an issue to these students.

These are not gifted students, their standardized test score from last years are ranked near the bottom of the whole nation. What made it so different in this classroom? I am positive that these students will perform better after this year with Ms. Washington. In the past few hours, the rate of increase in their knowledge and the habit of exercising their mind is accelerating. This is a Problem-Based Learning classroom.