Problem-solving in a Complex World: Integrating DISCOVER, TASC, and PBL in a Teacher Education Project

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Abstract

In the 21st century, one of the most important responsibilities for educators is development of students' ability to solve the multifaceted problems they will face in our increasingly complex world. Perhaps equally critical is that students develop a true understanding of the interactions among people, development, and the natural environment; and how the resulting interdependence can shape present and future conditions for all living beings.

In this article, we describe a project in which teachers in the role of learners solved a real-life problem, experiencing the interaction of factors and ideologies, and while learning the content of science also learned new ways of teaching. First, we provide a brief introduction to the integration of Thinking Actively in a Social Context (TASC) and Discovering Intellectual Strengths and Capabilities While Observing Varied Ethnic Responses (DISCOVER), then we discuss Problem Based Learning (PBL) and its relationship to both DISCOVER and TASC, and following this discussion, we describe the teacher education project. The description of the teacher education project includes the goals of each of three phases, introduction of TASC, the PBL activity (including content, field experiences, and development of problem-solving skills), use of TASC to structure group work, and integration of the DISCOVER problem types into the PBL experience.

DISCOVER and TASC

DISCOVER and TASC have similar goals: development of problem-solving abilities in children, youth, and adults. Interestingly, however, the two programs have a slightly different focus, thus each supplies a dimension that complements the other. In the DISCOVER project, the emphasis has been on assisting teachers in designing curricula and learning experiences in which learners are exposed to a variety of problem-solving situations, both those with a high degree of structure and those with little or no structure, as well as those encountered in various domains of ability (e.g., linguistic, scientific, mathematical, spatial, mechanical/technical, spiritual, social, emotional, somatic or bodily, and auditory). The basic premise is that by experiencing the solving of problems with a wide range of structure, learners will develop domain-specific knowledge and skills while they apply (and enhance) more general competencies such as creativity and critical thinking.

The emphasis of the TASC program, on the other hand, has been on the *processes* learners use in solving problems, regardless of their structure or the domain of knowledge involved. When learners use the TASC Wheel, they have a clearly-defined, but flexible, set of steps to follow as they work individually or in small groups to solve a real-life problem or develop a school project. The essential premise of TASC is that learners will be more likely to develop the competencies they need and more effectively solve the problems they encounter in school and in real-life situations when they learn methods to use during the problem-solving process.

After many lively discussions filled with examples of the ways the two programs helped children, Belle Wallace and June Maker designed an action research project in which the integration of the two models was tested in three UK primary schools (Wallace, Maker, Cave, & Chandler, 2004). In these schools, teachers, pupils, and parents made many positive comments about the experiences they had during the TASC/DISCOVER week and subsequent experiences with this integrated approach. As teachers continued to apply the integrated model, they learned much about their teaching, watched children grow in confidence as they applied the processes they had learned, and expanded the types of problems they presented to the students as well as the domains in which students were allowed to demonstrate their knowledge. In the book resulting from this project (Wallace, et al, 2004), many practical ideas are available to help educators apply the models in their schools and classrooms.

As the action research project (Wallace, et al., 2004) was being implemented in the UK primary schools, June Maker and Robert Zimmerman tested the integrated model, combined with Problem Based Learning (PBL), as a way to structure a project for adult learners. For two years, DIS-

COVER, TASC, and PBL formed the basis for a teacher education project for teachers of gifted children in math and science (both elementary and secondary) from South Korea. Although we believed strongly that the versatility of the two models made them ideal for use at all educational levels, testing this assumption was essential. Based on our experiences in the project, we believe that the DISCOVER/TASC/PBL model is indeed an approach that can be successful in teacher education; and its subsequent use by teachers who attended the program shows its value in the teaching of upper elementary, middle, and secondary school learners.

Because the focus of this special issue of *Gifted Education International* is on TASC, its underlying principles and development are not emphasized in this article. Instead, we provide examples of the ways the TASC model was taught to the teachers and a description of how it served as the structure and organization for the work of small groups and their discussion leaders. However, because DISCOVER and PBL are not included in other articles, a brief introduction is provided for these two models and how they are related to TASC.

DISCOVER and PBL

Like DISCOVER and TASC, DISCOVER and PBL have similar purposes. Their developers share a common belief in the importance of providing many opportunities for learners to solve meaningful, real-life problems. Problem-based learning was developed first in medical schools (Gallagher, 1997) because what students were learning in medical schools was consistently and markedly different from the skills and knowledge of practicing physicians. In essence, what these medical educators noticed was that the academic learning in schools often requires analytic and synthetic intelligence, but not practical (Sternberg, 1985; 1997). Problem based learning, when used in an academic situation, provides a context in which knowledge and skills deemed important in a discipline are applied in a real-life situation—thus integrating the traditional analytic and synthetic abilities with practical ones. PBL is used frequently in science education (Mergendoller, Maxwell, & Bellisimo, 2006; National Research Council, 2000), and is a popular model in many programs for gifted students (Maker & Schiever, 2005); however, it is a useful approach in many academic disciplines with all levels of learners, and is a way to break down the traditional barriers between disciplines.

Similarly, DISCOVER was developed by educators of gifted students (Maker, 2001; Maker & Schiever, 2005; Schiever & Maker, 1991, 1997) who were interested in designing academic programs in which students develop both knowledge and skills in academic disciplines and the ability to apply their knowledge and skills in real-life settings. In addition, they were concerned about students' development of both critical and creative thinking. Drawing on the research of Getzels and Csikszentmihalyi (1967, 1976) who found that students who were the best at solving "ill-structured" problems while in art school were the most successful creative artists later in their careers, Maker and Schiever modified the continuum of problem situations used in Getzels and Csikszentmihalyi's research to make it more practical and useful for teachers. One of the basic ideas in Getzels and Csikszentmihalyi's work was that when solving ill-structured problems, students are not simply reactive problem-*solvers*, but also are proactive problem-*finders*. Maker and Schiever noted that the continuum of problem situations designed for the research did not provide teachers with a way to assist students in becoming more proficient in solving these ill-structured problems, so they added three problem types to help both teachers and students move gradually from well-structured to ill-structured problem-solving experiences.

Thus, PBL and DISCOVER have similar underlying principles, but are different enough to complement each other. A PBL learning experience includes an ill-structured, complex problem involving substantive content considered central to the discipline being studied, and students work together in small groups to solve the problems. The teacher acts as a facilitator, leading the groups through the problem-solving process, and may introduce new content or ideas to make certain the groups learn to recognize that real-life situations are not simple problem-solving exercises with certain answers. A DISCOVER problem-solving experience also involves substantive content, usually organized around an interdisciplinary theme such as systems, interdependence, cycles, patterns, relationships, and other similarly broad-based ideas. The ways of presenting problems can be different depending on the goals of the teacher, and sometimes include presenting a series of problems beginning with well-structured ones, and as students gain more knowledge and confidence, presenting problems with less structure. At other times, the teacher can begin with an ill-structured problem, and in the context of solving that ill-structured problem, assist students in acquiring the knowledge and skills needed through introducing structured problem-solving experiences. Still another approach is to allow students to choose the level of structure of problems they wish to solve. Eventually, students are encouraged to propose their own investigations, and to design research to answer self-generated questions (e.g. problem-finding). In both models, students are *active* problem solvers rather than *passive* recipients of knowledge.

When combining DISCOVER and PBL, we chose to begin with an ill-structured problem, and to assist learners in acquiring knowledge and skills needed to solve that problem through field experiences, discussions, lectures, readings, and other exercises consisting of more structured problem-solving. For example, learners first were introduced to a situation in which developers are considering building a large number of new housing units on a river that begins in a rural area in Arizona, flows South into Mexico, then flows North back into Arizona through rural and urban areas. Groups of learners were assigned various roles of stakeholders in the problem situation, and asked to propose a solution. Structured problem-solving experiences included testing the water at a crucial point on the river, assessing the condition of the Riparian system at a critical point, using a Global Positioning System tool to locate the point at which tests were made, and participating in a restoration project funded by developers who previously had built large projects near the river, destroying valuable riparian systems. TASC was the structure employed by the teachers and by small-group leaders to assist groups in their problem-solving processes. How these models were combined, along with examples of their use in the project, is explained in the remainder of the article.

Goals of the Institute

The major objective of the institute was to use active, hands-on learning integrating four teaching-learning models in a teacher development project. The leaders of the institute intended to demonstrate "best practices" for teaching science and math to gifted students, methods that also could be used effectively with all students. The goals of the institute were accomplished in three phases. The purpose of Phase I was for teachers to *experience and learn*. In this phase they (a) experienced and learned new math and science content; (b) used models recommended for gifted students; and (c) experienced teaching appropriate for gifted students.

Phase II included *observation and analysis*. The teachers (a) observed others teaching gifted students; (b) analyzed and compared methods for teaching science and math to gifted students; and (c) learned principles and methods for applying teaching and learning models.

In Phase III the teachers *applied and created.* They (a) applied and created new science and math content; (b) applied teaching methods appropriate for gifted students; and (c) created teaching and learning units for students using models appropriate for gifted students.

In this article, we focus on Phase I: *Experiencing and Learning*. We followed the central principles of problem-based learning. We selected a complex, real problem with multiple solutions in which teachers would participate actively and control the direction of learning and discussion. We emphasized the specific content related to alteration of a scarce resource—water—in a specified watershed rather than the general global problem of water scarcity. The stage was set for them to solve the ill structured problem using a combination of four different teaching/learning models in an integrated fashion: TASC, DISCOVER, PBL, and the Hilda Taba Teaching Strategies (Maker & Schiever, 2005).

Introduction to TASC

Although some teachers had previous experience with Creative Problem-solving, none had used the Thinking Actively in a Social Context (TASC) model for problem-solving. Based on experience the previous year and recommendations from Belle Wallace, we designed a TASC day to familiarize learners with the process in a fun, easy problem-solving situation before they applied it in a more complex situation involving various groups and experiences. To begin, teachers were divided into groups of 6 to 8. Each group had a facilitator who had learned and practiced the TASC process, and each group was given a box containing materials for making a mechanical toy. These materials are called "Capsela," are available commercially in kits of various sizes, and can be used to create toys that move. Each group also had a colorful TASC Wheel with descriptions of the steps translated into the Korean language.

Gather/Organize

When each group received its kit, teachers were instructed to explore the material and discuss what group members know about building mechanical toys or about making something from these materials. Some groups explored each piece systematically while others began building something to test their knowledge or demonstrate their skill.

Identify

Teachers were given the task of building a vehicle. It could be any vehicle they wished to build. The facilitator, who was one of the directors of the institute, led the teachers in a discussion of what makes something a "vehicle" as well as some possible vehicles. All questions about the task were answered, and teachers were told they could make a familiar vehicle or a vehicle they imagined.

Generate

Each group then created at least three sketches of designs for vehicles that they thought they could build. In some groups, all members worked together to develop all three designs, while in some other groups, the three designs were created simultaneously by individuals or sub-groups and then shared with the large group.

Decide

Next, each group discussed the three designs, thought about criteria for selecting the best design, and then selected the one they would build (Photo 1). An important part of this process is to list several possible criteria for making choices, and to apply these criteria to each idea so that the best can be chosen rather than the favorite of an influential member of the group!

Implement

At this next step, the room was buzzing with activity (Photo 2). Teachers tried several designs, found that some of their drawings were unrealistic, found that some were useful, and often were surprised at the mechanical skills of their members. Some groups combined elements of the three drawings, and some abandoned all of them. Members of the groups cooperated in accomplishing their task (Photo 3). All groups were successful in creating a vehicle that would run on its own power. We took lots of photos and videos of the products.

Evaluate

After all groups completed their task, we held a large-group discussion about the importance of each group's self-evaluation of both its product and its problem-solving process. Next, the large group generated a list of criteria teachers thought would be appropriate for evaluating the vehicles: movement, stability, originality, complexity, usefulness, speed, multifunctionality, design, cost, and size. Then, we listed the criteria that could be used to evaluate the group's problem-solving process: cooperation, patience, use of trial and error, persistence, concentration, willingness to listen to opposite opinions, attitude toward others' opinions, acceptance of others, resolution of disputes, and motivation.

Each group then chose at least three of the criteria from each category, criteria they believed were most important in deciding on the overall quality of their product and process. They applied these criteria to their constructions and to their memories of how the group worked together in creating its vehicle. This exercise was a new experience for many of the participants, as they were not accustomed to evaluating their group work, nor were they familiar with generating and choosing their own evaluation criteria rather than having those criteria selected by group leaders, facilitators, or the teacher. Some groups continued to perfect their vehicles so they could give a higher score on some important aspect of the product.

Communicate

The groups now were ready to tell others about their work. Each group showed its vehicle, demonstrated how it worked, and talked about how it met the criteria they had selected as important. At the end of each presentation/demonstration, they discussed their group processes, sharing the criteria and results of their self-evaluations. A lively competition was evident as each group demonstrated how its vehicle was better than the others!

Learn from Experience

The final step was for all participants to reflect on the whole process and talk about their learning (Photo 3). Each group reviewed the TASC Wheel and reflected on each step of the process, sharing ideas about what they had learned. Group members discussed how they could work more effectively together, how they could learn more about vehicles and their development, and how their vehicles could be improved. Because they were teachers, we also asked them to reflect on ways this process could be used in their own teaching. We listened to their ideas about how the activity could be improved.

Application of the TASC Process during PBL

After the experience, the groups discussed the ways TASC would structure their work in the following few days as they worked together to solve a larger, more complex problem. We talked about the role of the group leaders as well as the role of the facilitators and the expectations of group members. In the following section, the PBL activity is described, and following that description, we review the use of the TASC Wheel in structuring the small and large-group work.

The PBL Activity

Content

The participants first were given information on problem-based learning and how it would be used to increase their experience and improve their learning about a specific topic. The science of *ecosystem ecology* was selected as the educational point of reference for teaching complexity. In ecosystem ecology, the link between organisms and their physical environment is emphasized within an Earth Science context. Ecosystems consist of all the organisms in an area and their interaction with the physical environment. Interactions range from those at the soil-air interface through watersheds to global climate. The study of ecosystems integrates the principles of other science disciplines such as community, physiological and population ecology, climatology, hydrology and soil science (Figure 1). In addition, *ecosystem management* is a concept that integrates ecological, socioeconomic, and institutional perspectives (Figure 2) in search of acceptable long-term sustainable management practices. It is an adaptive community-based approach to the management of ecosystems. In ecosystem management, the concept of *experimentation* is applied to the management of natural resources and to the design and implementation of environmental policies. Ecosystem management brings the local community into the learning process, and builds partnerships through citizen involvement (Civic Science).

The experience and learning activity was related to a real problem about the future of the Santa Cruz River near Tucson Arizona. Continual pressure for water usage and development was being placed on this fragile riparian ecosystem. The Santa Cruz River starts in the State of Arizona (Figure 3) in the San Rafael Valley (Photo 4) and flows south into Mexico before turning north back into Arizona and continuing past Tucson (Photo 5). Year- round water flow occurs only at the headwaters (point O on the map in Figure 3) and north of the sewage treatment plants near Nogales and Tucson, Arizona.

The teachers were divided into working groups (6-8 persons per group), given a facilitator, and assigned to stakeholder associations that were interested in preserving or using the resources of the Santa Cruz River. Stakeholder groups included the Santa Cruz Development Association, an Indian Tribal Council, the Santa Cruz Green Environment Agency, the Santa Cruz Resident Association, the Mesquite Bosque Biodiversity Society and the Agricultural/Mining Consortium. Each group had a list of questions to consider when examining problems along the Santa Cruz River from the perspective of a particular stakeholder group:

Santa Cruz Development Association. Along the Santa Cruz River, one of the most important industries is housing development—providing quality housing for people who live and work in Tucson and for those in retirement. What does development need from the Santa Cruz? How does the present problem contribute to not being able to meet these needs in the future? What has development contributed to the problems along the Santa Cruz? What might the Santa Cruz Development Association be willing to do to resolve Santa Cruz's problems?

Santa Cruz Residents' Association. The residents who live along the Santa Cruz are concerned about the river and its impact on their lives. They love living near it, and they also want to protect their property investment. What things about the Santa Cruz River are important to them? Could the residents be contributing to its problems? If so, how do they contribute? How can the Resident's Association help solve these problems?

Santa Cruz Tribal Council. The Native American Indians along the Santa Cruz are represented by the Santa Cruz Tribal Council. They have had a long history with the river and were the first to live in the area. What significance does the river have for their culture? They recently have returned to farming based on the principles of sustainability. What things about the Santa Cruz would affect their plans to develop small scale sustainable agriculture? Are they themselves contributing to the problem? What can the Tribal Council bring to the Commission to help resolve these problems?

Santa Cruz Green Environmental Agency. Santa Cruz Green is made up of citizens and professionals who are concerned about the environment of southern Arizona and in particular the Santa Cruz River Basin; both in the USA and Mexico. They are very concerned about the impact of unregulated development on the long-term sustainability of the Santa Cruz ecosystem. What do these scientists and citizens see as most important about the River? What are some short-term problems and solutions? What are some long-term problems and solutions? What is most important to do now? What is most important to do to prepare for the future? What help does Santa Cruz Green need from the other concerned groups?

Mesquite Bosque Biodiversity Society. The Mesquite Bosque Biodiversity Society is a unique cross-border ecological association concerned with migratory birds and the importance of the riparian mesquite forest as an ecologically important flyway. The Society promotes the preservation and restoration of mesquite bosques throughout the Sonoran desert. What do you consider to be the most important concern of this group? How do you think they can interact with the other groups involved? What evidence do they have that shows that biodiversity decreases when mesquite bosques are removed? What help do they need from the other groups?

Agricultural/Mining Consortium. This is a unique alliance of agriculture and mining. Both groups use substantial amounts of ground water. The agriculture group feels pressured because its members are the major consumers of water in Arizona. The mining group is concerned because of the fluctuating market for its products and the lack of public awareness of farmers' and miners' needs in the Santa Cruz River Basin. The increased consumption of water by residential communities threatens water quotas. How is mining and agriculture contributing to the problem? How do you think they could resolve the problems associated with water consumption in the short and long term? What compromises can be made by agriculture to insure the protection of the riparian habitat? Can mining groups overcome the bad perception the community has of them?

To assist the teachers with solving the Santa Cruz Problem a scientific report entitled *Water and Riparian Resources of the Santa Cruz River Basin: Best Management Practices for Water and Resource Quality* (SCERP Project No. WQ93-12) was provided. Each group was asked to read and discuss this report, considering the following questions:

- How do the authors of the report measure the health of the Upper Santa Cruz River Basin?
- What biological measurements are taken to assess its health status?
- Why did the scientist select these measurements?
- What is the health status of the Upper Santa Cruz River Basin?
- Does the report include information to support your group's goals?
- How can you use this report to defend your group's decision?

Additional background information on water quality, the importance of riparian habitats, future potential problems along the Santa Cruz and web-based information was provided to evaluate the ecosystem. Participants were given a glossary of scientific terms on ecology and riparian ecosystems. Teachers also had access to the internet and the libraries at the University of Arizona during the Institute.

Field Experience One

To understand better the problems facing the Santa Cruz River, we took a field trip to Tumacacori National Historical Park along the Santa Cruz River. The field trip provided a hands-on experience of the riparian habitat. The purpose of the field visit was to assess the condition of the riparian environment associated with each group's role in solving the Santa Cruz Problem. The specific aims were to (a) evaluate the water quality of the Santa Cruz River; and (b) appraise the condition of the riparian vegetation along the Santa Cruz River. Each specific aim had equipment and materials to measure, record, and evaluate the quality and health of the river. Background scientific data were provided so participants could compare their results with data previously collected.

Water Quality Analysis. Each group had a LaMotte® Green Kit to analyze water quality. The kit contained materials necessary to measure key parameters such as temperature, dissolved oxygen, nitrates, and pH. Two sites along the Santa Cruz River were compared. Participants recorded data on a water quality field data sheet, analyzed the data and compared their results with previously collected data found in the literature (Photo 6).

Appraisal of the riparian habitat. Two exercises were done in this activity. The first exercise gave the participants experience with a geographical positioning system (GPS). They were to delineate (draw and connect points) the boundary of the study site and map any environmental impacts they noticed, including trash, off-road vehicle damage, and non-native plants. A handout on GPS and environmental impacts was provided.

The second exercise demonstrated how to measure the health of the riparian habitat. Participants used technical guidelines for conducting riparian assessments developed by the government of Australia (Jansen, Robinson, Thompson, & Wilson) during this exercise. For example, they measured perpendicular transects (n=4), 100 to 200 meters along the river and marked points every 50 meters with a GPS. They used a scale of habitat quality to score habitat features at each point. They scored the degree of riparian vegetation, cover and native plants (canopy, ground and understory), and debris (leaf, dead trees and fallen logs). They then weighed and averaged the scores for each index and compared their results with those of the other stakeholder groups.

After the groups had analyzed water quality and riparian vegetation data, and were working on their proposed solutions, they were surprised with a new development in the situation. To demonstrate the changing nature of social issues and political solutions, the teachers were given a newspaper report saying that a development organization was willing to mitigate potential damage caused by a housing project by restoring another portion of the Santa Cruz River back to its natural state. Additional background information on restoration ecology and mitigation was provided to the teachers so they could better evaluate the impact of this offer.

Field Experience Two

The Tucson Audubon Society was carrying out a restoration project along the upper portion of the Santa Cruz River. Teachers listened to a lecture about the project and made a visit to the site. Teachers were given the chance to participate actively in the restoration.

Proposed Solutions

A major objective of Phase I of the Institute was for the teachers (groups) to defend their proposed solutions in front of a mock county commission. This provided the teachers with an additional learning experience—organizing, presenting, and sharing information they obtained during the activity with the general public. Examples from three of the stakeholder groups are the following:

1. Members of the *Santa Cruz Green Environmental Group* opposed the development project. Their general position was that the planning commission should protect the natural environment, including the quality of the water. The speaker wore a sign saying "We have to protect nature." She presented information about the quality of the water (levels of dissolved oxygen and nitrates) based on the analysis performed by her group and information about water quality gathered from other reports.
2. The position of the *Santa Cruz Residents*' *Association* was that the river could not support any new housing developments. During the presentation, other members of the group were holding signs: "The development is the death: We oppose the development project." We want to drink clear water." "Excellent condition of life rather than wealth!"
3. The Native American leader of the *Santa Cruz Tribal Council* gave a speech about the values of his people and their need to live on the land. Members of the tribe accompanied him to the presentation dressed in their native clothing, singing their native songs, and bringing an emotional tone to the discussion. They described their use of the land, and how the proposed development would disrupt their farming. This group opposed the development project.

Presentation Evaluation

At the beginning of the PBL activity the teachers were given a list of seventeen criteria that would be used to judge the stakeholder presentations. The criteria included "Is the presentation persuasive?", "Is it engaging and interesting?", "Are sources cited?", "Are the water quality and riparian issues addressed in detail?" and "Do the ideas for further research demonstrate that presenters understand the complexity of the ecosystem?"

Content Knowledge Evaluation

A pre-assessment of content knowledge of ecology was conducted. This was followed with a post-assessment of knowledge at the end of the PBL activity. For a description of the methods used in conducting the discussions, see the Gather/Organize section of the TASC description in the next paragraph. In the post discussion, the overall number of elements of knowledge increased from 16 to 38. More specifically, more living elements (e. g., plants, animals, and microorganisms) and non-living elements (e. g., air, sunlight, temperature, mountains, fire, seasons, and pollution) were included in the post assessment. In the post assessment, participants also listed a greater variety of living and non-living elements. Humans were included in the second discussion, but not in the first, reflecting understanding of the relationships between people and the natural environment (See Photo 7, pre-assessment and Photo 11, post-assessment). When participants were asked to make groups of items and provide labels for them, these answers reflected a greater understanding of the elements and their relationships, including hierarchical ones. Flexibility of thinking also increased as more types of elements were listed in the post-assessment discussion. In essence, participants began thinking more like experts and less like novices (Chi, Feltovich, & Glaser, 1981).

TASC as a Structure for Group Work during PBL

Gather/Organize

Hilda Taba's (Maker & Schiever, 2005) first teaching strategy, concept development, was used to help facilitators, small-group leaders, and learners to gather and organize their knowledge about ecosystems, the content focus of the PBL experience. Learners were asked "What are the elements of ecosystems?" As each person listed information, it was written so all could see, and clarifying questions were asked if needed. No responses were evaluated, and all were accepted. Teachers listed trees, lakes, grasshoppers, fish, sand, rain, cactus, sun, clouds, and many other components of ecosystems (Photo 7). Next, as a large group, learners were asked to tell which of the elements could go together because they were alike in some way. As each individual suggested a group of elements, he or she was asked to tell how these elements were alike. When a variety of groups had been made, each group of elements was discussed and at least three titles were sought based on the reasons for putting the items together in a group. Following this exercise, learners examined each group and all the labels for groups, searching for items and labels that could be subsumed under other items or labels. In essence, they were determining how their ideas were related in hierarchical order.

At the final step of the discussion, learners were asked to generate additional elements, and then to re-group the items in ways that were completely different from the ways the elements had been grouped previously. Small groups worked together on this activity, and then reported their results to the large group. Not only did this experience introduce the group members to each other's knowledge base, but it also helped everyone organize and classify their knowledge.

Identify

At this point, learners were introduced to their problem-solving task, which included a presentation with photographs taken at various points along the river. Each group was given a role as a stakeholder (e. g., developers, residents, Native American farmers) in the Santa Cruz River problem. They asked questions to clarify the task. During this step of the TASC process, learners also listed additional information they needed to have before they could generate solutions and began to clarify the position they might take as a particular stakeholder. Some information was given to help structure these positions, but learners still needed to determine specific foci for their efforts.

Gather/Organize

At this point, learners needed to return to the first step, based on their new knowledge of their task, and to gather information about river ecosystems, the Santa Cruz River, the possible values and ideas of their stakeholder group, solutions to similar problems, ways to handle international border situations, and other pertinent facts or ideas. They collected and organized information from the internet, materials provided by the facilitators, and from their field experiences. They analyzed information from the assessment of riparian conditions and from their testing of water quality. Facilitators and group leaders assisted in synthesizing and putting information from field experiences into a form all could use. The biggest task was to use the GPS coordinates to make a large map showing information about the riparian assessments at different points on the river (Photo 8).

Generate

Learners began to generate ideas for solving their problems, and to discuss these possibilities during the gather/organize step, and continued with the assistance of small-group leaders. Facilitators arranged time for all small groups to work at the same time to brainstorm possible solutions, and reviewed the rules for brainstorming: quantity rather than quality is the goal, accept all ideas from other group members, defer evaluation, and share all ideas regardless of how silly they may seem. Group leaders assisted their groups in using the principles of brainstorming to list as many ideas as possible.

Decide

As a large group, we listed sample criteria that could be used to evaluate the solutions and decide which one(s) to implement: cost-effectiveness, potential to be successful, practicality, creativity, satisfies the needs and interests of the stakeholder group represented, innovation, and meets legal requirements. Each group then selected appropriate criteria and evaluated its list of possible solutions. Final solutions often were combinations of the highest-rated ideas, and in some cases, because the solutions listed did not meet some of the criteria, the solutions were modified so they met more criteria.

Implement

Due to the nature of the problem, groups were unable to implement their solutions. However, they drew diagrams, developed plans, and worked out as many details of their solutions as possible. Another aspect of this step was giving the groups a surprising development (proposed mitigation) and participation in a local restoration project. Learners planted trees and shrubs, identified wildlife, and talked with volunteers at the restoration site.

Evaluate

After experiencing the restoration project and considering this alternative, the groups re-assessed their plans and decided on the role of mitigation in solving the Santa Cruz River problem. They discussed their experiences in the field and evaluated their plans to determine if and how they could incorporate mitigation (Photo 9).

Communicate

As they prepared to communicate their solutions, groups were given a simple outline of important points to remember as they planned what to say: (a) State the problem [be realistic, provide evidence of the seriousness of the problem, be brief and clear]; (b) Propose your solution [provide evidence that it will work, describe its benefits]; (c) Explain what the planning commission can do to implement your solution [keep the solution simple, give a time frame for the actions]; (d) Conclude with a statement of the benefits that this group will get by doing what you suggest [guilt does not work, avoid threats, avoid criticizing other individuals or groups]. Each stakeholder group presented its solution to the City Planning Commission, which consisted of the facilitators of the institute, but ideally would include individuals from the local community involved in planning and zoning. The Planning Commission asked questions and made comments about the presentations. Excitement was evident as each group presented its innovative solution in interesting and engaging ways! PowerPoint was a favorite medium; the use of models, diagrams, and other visuals supplemented the presentations. The group representing the residents of the nearby housing projects even held a demonstration. The Native American group came dressed in Native clothing, and its leader made an impassioned speech about how the land was important to them, and should not be destroyed (Photo 10). The developers had an interesting plan that included a buffer zone and an open area for a park in the middle of a dense community of homes.

Learn from Experience

The first aspect of this step was to complete a self- and peer-evaluation of the plans and presentations. Each group completed an evaluation of its own presentation and solution as well as an evaluation of the presentations and solutions of the other groups. The second aspect of the step was to participate in a post-assessment of content knowledge. A second concept development discussion was held. Participants again answered the question “What are the elements of an ecosystem?” They listed a variety of elements, grouped together elements that were alike in some way, generated labels for each group based on the reasons the items in the group were alike, and explained why each label was appropriate. Next, the participants examined the groups, labels, and items, and determined which could subsume others—again exploring the hierarchy of ideas and concepts. These steps were completed in a large group, and then each group was asked to examine the original list to see which items could go together in ways completely different from the original ways they had been grouped (Photo 11). They grouped and classified these ideas, then presented their groupings to the larger group. An interesting exercise would be to ask learners to examine the original list and the groups to determine how their thinking had changed as a result of the problem-solving experience.

Integration of DISCOVER Problem Types into the PBL Experience

The DISCOVER Problem-solving Continuum (Maker & Schiever, 2005) consists of six distinct, but related, problem types. In this continuum (Schiever & Maker 1991; Maker & Schiever, 2005), problem-solving situations are classified according to what extent the individual who presents the problem (usually the teacher) or the person who solves the problem (usually the student) knows the problem, method for solving the problem, and the solution. In other words, the continuum is based on the amount of information or structure in the problem situation presented. Types I and II are well-structured, requiring mostly convergent thinking, and students must reach the correct or best solution determined by the teacher or author of the test being given. Problem types at the other end of the continuum (Types V and VI) are open-ended and unstructured; they require a balance of divergent and convergent thinking and the problem solvers have to decide the best or correct solution from their own perspectives. Types III and IV, in the middle of the continuum, provide a transition so that both teachers and students can move from the familiar structured learning and teaching situations to more ambiguous and often unfamiliar ones. In Figure 4, we show how the problem types are related to the PBL experience. The circle represents the Type V problem (the Santa Cruz River problem), which is open-ended, but has some structure. The structure comes from the fact that a problem statement is given to the learners and they are assigned roles as stakeholders.

The Type I, II, III, and IV problems are embedded in the Type V problem-solving. For example, during the first field experience, the participants used specific equipment to test the quality of water in the river. The problem is clearly stated, one method is used, and this method leads to one clear answer, a number, indicating the levels of certain pollutants in the water. During the second field experience, the teachers were shown how to cut a branch from a particular type of tree and to plant it in an appropriate place. They also were told how to plant native shrubs (Photo 12). All these experiences were Type I problems because the problem, method, and solution were clearly structured. The learner has to follow the instructions and use the correct method. The Type II problem was to apply a particular method for assessing the condition of the riparian system around the river (Photo 13). In this case, the problem was slightly less structured, with more individual variation in the application of the system for assigning points to the condition of the elements of the ecosystem.

The main Type III problem incorporated into the PBL experience was to organize data for use during the presentations. In this type of problem, learners have a clear problem, which is to present a certain type of information such as changes in water quality from one point on the river to another. The method, however, is open and flexible. They can use bar graphs (Photo 14), line graphs, pie charts, tables, maps, photographs, and other appropriate formats. However, regardless of the method used, the data already have been identified, and are known prior to solving the problem of how to present them.

The Type IV problem-solving experience was participation in two Hilda Taba Teaching Strategies discussions. The Concept Development discussion (listing information, grouping, labeling, subsuming, and recycling all the previous steps) was described in the section on the use of TASC (Gather/Organize, Photo 7, and Learn from Experience, Photo 11) during the PBL experience. Students also participated in another discussion, Taba's Interpretation of Data strategy. In this discussion, they were asked to list results of their assessment of water quality, then to infer possible causes and effects of these results. Open-ended, focused questions are used by a discussion leader to stimulate thinking about a variety of causes for each result, then to infer causes of these causes. Similarly, questions are used to engage learners in thinking about effects and effects of the effects (long-term effects). In all cases, when a cause or an effect is given, reasons or support must be provided. After many possible causes and effects are listed, participants make conclusions about the most important causes and effects, then write general statements about the causes and/or effects of data similar to what they have discussed. This is a Type IV problem-solving situation because the "problem" is stated clearly and structured (the question is focused on a particular piece of data and students are asked "What do you think caused ___?" or "What do you think are some of the effects of ___?"), the method they use to make their inferences is open, but they must explain it, and a range of answers (solutions) is possible for each question. Some answers and some ways of reaching answers might not be defendable, which is why this is a Type IV problem situation rather than a Type V.

In a Type VI, students must identify their own problems. During the solving of the Santa Cruz River problem, students had the opportunity to think about the myriad of challenges faced by various stakeholder groups as well as the need to manage the river system in a setting involving two countries. In a semester-long or year-long teaching situation, the Type V problem-solving experience would be an important way to stimulate students' thinking so they could spend a large portion of their time designing and implementing their own investigations. In this short-term teaching setting, however, each group was asked to propose other studies that need to be done prior to making decisions about whether to allow further development on the Santa Cruz River. Some examples of studies proposed are the following: (a) Study the condition of the riparian habitat at several places along the river, and determine where the major problems begin. (b) Test the water at different points of the river at different times of the year, compare these tests with information about water quality from the past 10 years, and determine whether the overall quality has declined significantly, and where this has occurred. (c) Study the farming techniques used by the agriculture and mining consortium and by the American Indians to determine which have the least harmful effects on the water level and quality.

Throughout Phase One of the Institute, teachers participated in experiences involving various domains of ability, another aspect of the DISCOVER model. Following are some examples:

- Mechanical/technical—making a vehicle;
- Mathematical—organizing data for presentations;
- Scientific—analyzing water quality, assessing riparian conditions;
- Spatial—making maps and drawing plans;
- Social—working together in groups to solve an ecosystem management problem;
- Emotional—taking the perspectives of various stakeholders;
- Bodily/somatic—participating in the restoration, making vehicles;
- Linguistic—presenting/communicating solutions;
- Auditory—assessments of wildlife in the riparian system, identifying birds (by visual characteristics—spatial, and by calls and songs—auditory);
- Spiritual—participating in the solving of a problem in which deeply-rooted values are inherent, and being encouraged to identify solutions that will benefit both humans and the natural world.

Summary and Conclusion

After participants experienced the complexity of this real-life problem and began to understand how content from various disciplines could be integrated in the teaching process, they then were ready to observe other teachers and evaluate the experience from a different perspective. They watched master teachers and teachers who had not yet mastered this form of teaching, and then they worked together in grade-level groups to put their learning into an even more practical context by designing their own ill-structured problems to present to students in Korea. They planned discussions, searched for information about relevant problems that could engage the interest and motivation of their own students, and shared ideas with colleagues. Continued correspondence and two visits with the teachers have confirmed that they have used their teaching units and that they learned important universal teaching techniques. However, we believe strongly that long-term evaluation is important to confirm that the time, energy, and money spent on a project such as this has resulted in real, consistent change in teaching behavior, and to find out what elements are most important in producing long-term benefits to students.

The success of this exciting teacher education project shows the value of combining several approaches to development of the ability to solve the diverse and troublesome problems we face in our increasingly complex world. The models used complemented each other, with each one contributing a unique part, but all working together to accomplish the same goals. Although this approach to staff development was not familiar to many of the teachers, they were engaged constantly, presented interesting and creative solutions to the problem, and demonstrated increased understanding of the complex nature of ecosystems and the balance necessary to manage them effectively. We are deeply committed to continuing this work, and to designing programs in which both students and teachers participate in solving real-life, complex, critical problems at local, national, and global levels. We welcome partners in these endeavors!

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