

Why & How We Apply PBL to Science-Gifted Education?*

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Abstract

This study is based upon the reflections of two teachers and fifteen students as they experience problem-based learning (PBL) for the first time. A PBL exercise was integrated into a curriculum-based Earth Science field to meet specific learning requirements of gifted students. If you give affirmative answers to all these questions, it will not be the distinctive program for the gifted children (Passow, 1982). PBL is an educational approach where a purposefully ill-structured real-world problem initiates learning and the teacher serves as a coach instead of an information repository. Problem-based learning is currently used in the various disciplines. However, the field of gifted education does not yet implement this type of teaching and learning approach very often. In the present study the PBL implementation created a new learning environment for both students and teachers, and PBL was evaluated as an educative strategy. The application of the instructional approach could have been improved through more spontaneous student support. Interview analyses indicate that students favor learning via PBL, but some students suggest that embedding teacher-directed lessons within a PBL unit would benefit the students more than an exclusively PBL-based curriculum. So the overall contribution of this study is to show theoretical justification and the implementation of problem-based learning in developing optimal learning experience for gifted students in the domain of science, since this type of teaching and learning approach is considered most compatible with the characteristics of the gifted students.

Keywords

PBL, Gifted Education, Science Program, Teacher-Directed Learning

1. Introduction

Do all students want to participate in such program?

Can all students participate in such program?

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Will all students show a great achievement on such learning program?

If you give affirmative answers to all these questions, it will not be the distinctive program for the gifted children. What is exactly a distinctive differentiated program for the gifted children? As recently the interests on the gifted education have been increased, the requests for developing appropriate programs for the gifted children are pouring in from all quarters. However, programs for the gifted children, which consider their characteristics carefully and suit the defensible curriculum model, have rarely existed. It is true that the gifted children, like “the naked king”, have tended to be drifted without a proper program for them even after being identified. Current programs for the gifted children are mostly focused on acceleration and extremely difficult problem-solving questions. As a result, some problems have been brought up: such programs are inappropriate to trigger the intrinsic motivation from the gifted children, to simulate their interests on learning, or to increase the standard of their achievements. It is not deniable that some existing programs have been intent on preserving the present situation rather than developing the brilliant character of the gifted children. So, what kind of features must the educational programs for the gifted children have? A number of researches are presenting the goals or characteristics of the program for the gifted children (Maker, 1996; Van Tassel-Baska, 1996; Van Tassel-Baska & Kulieke, 1987), and **Table 1** shows how they should be discriminated from others in the regard of contents, processes, and products. However, it has always been troublesome for us to apply the disciplines of such discriminative education process to the real learning situations.

Table 1. Principles of curriculum modification.

Content	-Abstractness
	-Complexity
	-Variety
	-Organization
	-Study of people
	-Study of methods
Process	-Higher-level thought
	-Open-endedness
	-Discovery
	-Evidence/Reasoning
	-Freedom of choice
	-Group interaction
Product	-Pacing
	-Variety
	-Real problems
	-Real audiences
	-Transformations
	-Variety
	-Self-selected format
	-Appropriate evaluation

Faced with such problems, this study explores a problem-based curriculum for gifted children, which is based on constructive approach. In this study, a problem-based learning (PBL) exercise was integrated into a curriculum-based Earth Science field to meet specific learning requirements of gifted students, and the effectiveness of the PBL program was examined though it was a little bit limited.

2. Theoretical Background

2.1. What Is Problem-Based Learning?

PBL is one way to effectively manifest the features of programs for the gifted children. If asked what the important purpose of education is, most teachers will say, whether they teach normal children or the gifted, raising them to an effective and creative problem solver is the main issue in the classrooms. However, it will not be easy to educate such learners because our classrooms still have lots of problems. Various researches indicate that the current curriculums are rarely dealing with critical thinking skills or problem-solving ability. In fact, several researchers point out that above 85% of teachers' questions are concerned with requesting simple memory or comprehension, and questions dealing with higher level thinking skills or creativity such as synthesis and evaluation hardly exist (Trefz, 1996). This situation is quite same for the gifted education. In addition to that, the often-indicated problem is that the induction of students' motivation does not occur effectively, and classroom and real context are not linked with each other anymore because problems, which are too superficial and not related to real context, are often raised in the classroom.

Problem-based learning is currently used in the various disciplines. PBL has been described as "truly educative" and clearly illustrates its potential to encourage meaningful or deep learning (Birch, 2006). Despite of evidence to support such argument, the field of gifted education does not yet widely accept and implement PBL. PBL is an educational approach where a purposefully ill-structured real-world problem initiates learning and the teacher serves as a coach instead of an information repository. The biggest characteristic of the problem-based learning is that learning contents are introduced in the complex and real situations. In other words, the problem comes first. This is much different from the previous instructional type, which presents the problem at the end of the chapter after learning in a lecture. In the problem-based learning, students collaboratively solve very ill-structured complex problems in the real context. In the process of solving problems through learning in a small group, students have critical eyes, ask meaningful questions, and also automatically get to know what they should know to answer those questions and where they should get such answer. According to previous research, students can develop higher level thinking skills and creativity as well as necessary knowledge while solving such real-world problems (Trefz, 1996).

Unlike teacher-centered traditional classrooms, teacher plays a role as an assistant and students are centered in the problem-based learning. Through such learning, students learn and apply contents, develop critical thinking skills, up-

grade the quality as lifelong learners, and make themselves familiar with the communicative and collaborative ability automatically (Papert, 1991; Schulman, 1987). The quality as lifelong learners involves the abilities to distinguish known things from unknown things, find necessary information, use them properly, and arrange and organize them and etc. Also current researches suggest that the ability to think critically, solve complex problems, find information, evaluate them, use them properly, work as a team member, and communicate effectively by oral and written documents should be completed. The problem-based learning is an effective learning type for the gifted children in order to improve such abilities, and it is an appropriate learning method because it makes level-arbitration easy according to one's ability. Through the problem-based learning, students do science naturally and effectively rather than learn science, and become qualified to do science. Through the problem-based learning, students can naturally meet with scientific process and culture as little scientists. **Table 2** draws the image of students who pursue such learning type, and **Table 3** shows evaluation-standard.

2.2. The Problem-Based Learning and Science Gifted Education

Problem-based learning seems particularly appropriate for gifted children since it incorporates practices which are often recommended for programs for the gifted. Current researches show that the problem-based learning are effective in inducing the motivation of gifted children, improving mutual interactions between teachers and students, and students and students, developing the ability to

Table 2. Image of students that the problem-based learning pursues.

Self-directed learner
-Building up the priority order and an achievable goal
-Monitoring and evaluating the process
-Designing options for one's own self
-Taking responsibility for one's own activity
-Forming a positive vision about oneself and the future
Collaborative worker
-Monitoring one's own actions as a group member
-Evaluating and improving group's functions
-Developing communicative ability mutually
Complex thinker
-Using various strategies to solve complex problems
-Developing the ability to select proper strategies to solve complex problems and apply them correctly
Quality producer
-Making products which can achieve the goal
-Using proper resources and skills
-Making products which can reflect scientists' mind
Community contributor

Table 3. Evaluation-standard of the problem-based learning.

Evaluation-standard of PBL
-Does it emphasize higher level thinking skills?
-Does it emphasize deep knowledge?
-Does it indicate problems related to real context?
-Are inquiries and researches connected each other?
-Do teachers and students show mutual respect and strong collaboration?
-Do students have opportunities to achieve practical and unique products?
-Do the activities cultivate the spirit of adventure and inquiry and give students chances to go beyond the limit of one's own ability?

Table 4. The paradigm shift in the science gifted education.

The existing program	The direction of the required program
Teacher-centered	Student-centered
Content-focused	Content-and process-focused
Learners mainly hear about activities related to science.	Learners do science activities for themselves.
Scientific knowledge and activity are presented as hardened facts.	Scientific knowledge and activity are constructed and discussed socially.
The existing discovery or tangible facts are studied and memorized.	Scientific facts are discovered through observations and experiments in order to establish scientific theory.
The chance about reflection-in-action or reflection-on-action is insufficient.	The chance about reflection-in-action and reflection-on-action is sufficient.
Superficial learning	Deep understanding and learning
Leaning science	Doing science

discover and solve problems, and improving the ability to learn (Gallagher, Stepien, & Rosenthal, 1992; Stepien & Gallagher, 1993; Van Tassel-Baska, Bass, Ries, Poland, & Avery, 1998). Furthermore, such researches indicate that the harmony of content and process, unique research-based learning, development of scientific concepts, and interdisciplinary approach among diverse subject areas can be accomplished naturally through problem-based learning. The problem-based learning also advocates effectively things which science gifted education points to. **Table 4** shows the trend of science gifted education and programs needed currently through current paradigm shift (Adams & Callahan, 1995; Amabile, 1996; Fowler, 1990; Stepien & Gallagher, 1993; Trefz, 1996; Van Tassel-Baska, 1996).

3. Designing a PBL Unit

Through the maximum application of the characteristics of problem-based learning, 4 units 12 hours' amounts problem-based learning programs in the field of earth science were developed. The target of the development of programs was fifteen middle school second graders taking the intensive course of earth science subdivision in the Science Education Center for Gifted Children at the University of Incheon. The fifteen students were grouped into 4 teams having four members in each group, and they met every Saturday for one month.

There were wide variations in their backgrounds, experiences, preferred learning styles and expectations. The diversity of students was of particular significance in influencing the design and delivery of the subject. These variations offered tremendous potential in enriching the experiences of all students.

To illustrate the PBL approach utilized in the study, the problem statement should be introduced first.

Dear the members of Maritime Affairs and Fisheries Consultative Committee,

At the 21st century North-East Asia era, the western coastal region of Korea has geographical advantages of being the kernel of the hub of North-East Asia. Specially Incheon, which has a natural seaport, has been a central place for the national trade since early times. With a desire to become a hub of the North-East Asian trade, Incheon is currently planning to construct an international seaport. However, it is suggested that tidal effects must be considered as a very important factor when we construct the harbor. However, I could not understand the importance of the tidal effects on designing and constructing the seaport.

Not in eastern coastal region, the differences between the rise and fall of the tide are great in the peninsula's western coastal region, and Incheon has been a candidate for the national tide power plant. So I have a vague idea that the tide effects will be of importance.

To my embarrassment, I must confess that I am poor at the scientific understanding though I am a person in charge of the harbor.

I should be much obliged to you if you visit to our city hall to give a simple briefing about the tidal effects on designing the harbor at 8th May.

Hong, gil-dong

Mayor

The Metropolitan City of Incheon

This problem statement has three key features reflecting the principles of PBL. First, it is ill-defined: it is not entirely clear what the problem is. Second, the problem is a real-world problem: the problem was localized by choosing a site in their area. In fact, localizing the problem makes it more compelling to the students and allows the teacher to use local resources as the problem develops. Finally, the students are given a stakeholder's role in the situation and have both authority and the responsibility needed to be part of the problem's solution.

After students have read the problem statement, they discussed it as a group and worked on the "Need to Know" board. Need to know board, a metacognitive organizer, is used to help students organize their thought and the tasks they need to complete in order to make progress on the problem. The generic format for the Need to Know board is shown in **Table 5**. Students continuously modify it with new information and new questions.

Table 5. Need to know board.

What do we know?	What do we need to know?	How can we find out?

During the first two weeks of PBL exercise much emphases were placed on providing students opportunity to work with each other in group on clearly defined task for them to get used to group work and research project on their own. They also were encouraged to continue to work together collaboratively outside the classroom to share ideas and to talk through issues raised. The students began to engage in the process of problem formulation, started raising questions and sought for resources to solve their research problems in week two and three. To refine their problems, to develop an appropriate research design, to provide acceptable solution and to present their solutions to the teachers and peers, the four weeks period of 12 hours was too short.

4. Results and Discussion

In order to gauge students' responses to the subject and its impact on their learning, data was gathered through three principal mechanism; two stage student survey, students' reflections in their research journals and personal interview, and observer's field notes.

1) What survey has found out...

The survey involved a self-rating instrument of twenty questions, divided into three sections. The survey used in the study, Self-rating Instrument for Competencies of Self-directed Learning, was originally developed by Ryan (1993) and modified by Roberts (1998). The questions asked students to rate their level of involvement in learning environments, their confidence as contributors, the value of working with others, their capacity to evaluate their own work, their capacity to gain feedback about their work from others, the value of their peers as learning resources, their ability to question, analyze, and research, their ability to generate ideas, their capacity to identify their learning needs and address them and so on.

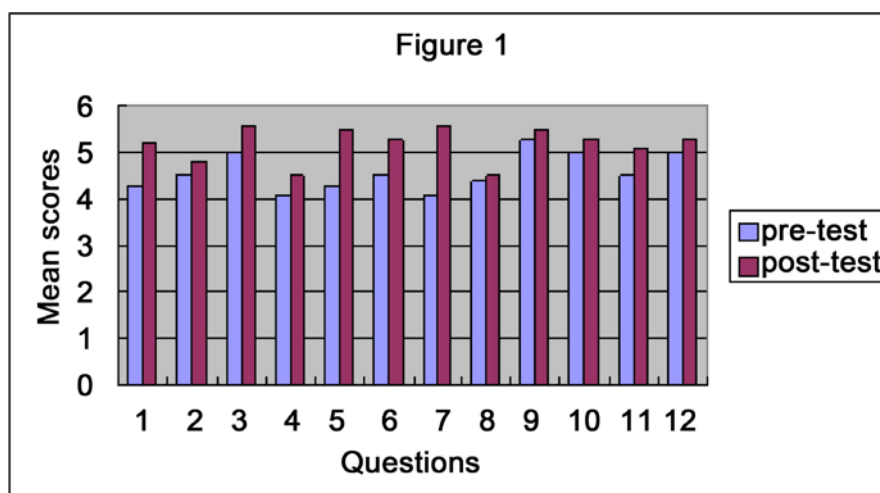
The self-rating instrument was completed twice by all participating students, before and after the PBL unit. Students were asked to rate themselves on a scale of 1 (very low) to 7 (very high). The results of the survey, expressed as means, are presented on **Figure 1** & **Figure 2**. And followings are questions of the survey utilized in the study.

Questions

1. How would you rate your level of involvement in classes?
2. How would you rate your level of confidence in contributing to class discussions?
3. How would you rate the value of working in group situations?

Continued

4. How would you rate your ability to evaluate your own work?
5. How would you rate your ability to gain feedback from others about your progress?
6. How would you rate your ability to decide what knowledge and skills to learn?
7. How would you rate the value of fellow students as resources for learning?
8. How would you rate your ability to select the most effective strategies to assist your own learning?
9. How would you rate your ability to generate questions?
10. How would you rate your ability to analyze problems?
11. How would you rate your ability to research issues?
12. How would you rate your ability to generate ideas?
13. How important do you think it is to be able identify your own learning needs?
14. How important do you think it is to be able to identify and locate a range of relevant resources?
15. How important do you think it is to be able to critically evaluate the scope and accuracy of information?
16. How important do you think it is to be able to evaluate the effectiveness of your application of this knowledge and skills to tasks?
17. In relation to my own learning I am able to identify my specific learning needs.
18. In relation to my own learning I am able to identify and locate a range of relevant resources.
19. In relation to my own learning I am able to critically evaluate the scope and accuracy of information I gather.
20. In relation to my own learning I am able to evaluate the effectiveness of my application of my skills and knowledge to tasks.



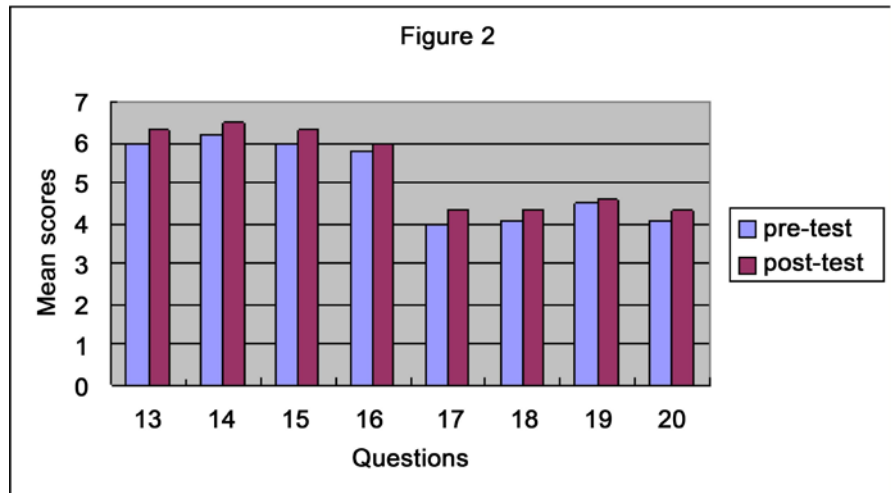


Figure 1 demonstrates that students have increased their capacity in relation to most of the items contained in the survey. Students indicated that, through the four times of PBL experiences, in particular they believed they were much more involved in class, appreciate the value of working in group, increased their ability to gain feedback from peers, considerably increased their ability to decide what knowledge and skills to learn, significantly felt the value of fellow students as resources for learning, and far better equipped to research issues and think creatively. **Figure 2** demonstrates how students responded to the questions related to perceived importance (13 - 16) and perceived ability (17 - 20) in core indicators of self-directed learning. Students responded higher on the questions related to perceived importance indicator of self-directed learning than on the perceived ability ones, though they showed increase across most of the questions. These findings are consistent with what Roberts (1998) has found out.

2) What are students saying about PBL?

It was the first time that students had been asked to reflect on their learning through writing and, although they were given initial guidance, there was no interim feedback or further support from teacher. Followings are what students say about PBL lesson through journal reflection and personal interview. Here I will share gleanings from the case vignettes of students.

PBL lesson was more radical than anything I had previously countered. Now I feel I have more responsibility for my own learning. This exercise definitely helped me to be more independent.

Unlike the past, the fact that students made the course of the entire experiment by themselves, conducted the experiment, and the teacher played a role as advisor was the most unique point...

The previous lessons had been done after listening to teachers' theoretical explanation of the experiment subject, but in last four times' lessons teacher's theoretical explanations were excluded as much as possible, and we had to solve by ourselves.

Because we had time to write a journal after the experiment, present and object, and synthesize, we were able to access to the problem one step further.

I think the problem and this type of lesson is very useful, since they kept us focused on thinking about learning issues and the solutions. We had to keep thinking about them.

Carrying out discussions and solving the various problem scenarios as a group improved my own learning process. This collaborative learning approach has helped me learn with and from others.

Deviating from experiment courses and results with the conventional methods, we could improve creativity and expressiveness. In the previous lessons we had time to think about the results after knowing the method, but in last four times' lessons we predicted the result and thought about the process, seeing the problems.

Even though I had a headache, it was fun. Last four times' lessons were different from fixed lessons because they gave us a chance to plan and make an experiment in each group. Through such lessons, we had an opportunity to hold together in-group and think creatively.

It was great that last four times' lessons were more candid and they accepted various plans, unlike the previous lessons. The previous lessons were also good, but it would be better that students are educated in the same way as last four lessons...

It was interesting to think about an experimental method and to conduct the experiment by one's own self. In order to manage questions asked from others, I first had to know much knowledge about the subject. Besides, I had a strong conviction of doing it well, but wrong results came out, but I had time to think about such results carefully. Through four times' lessons, I realized that the process was more important than the result.

Students' response, however, were not always positive. Some students expressed their hard times during the PBL lesson:

As the work progressed I began to recognize major limitations regarding my (and my friends') personal experiences and knowledge

I didn't feel like I was making any useful contribution to my group

Today was a complete mess and our team was awful! We totally missed the point of what we should be doing during the lesson

I feel the previous lesson was too superfluous. Embedding previous lecture lessons with the PBL type of learning would benefit us more than an exclusively PBL-based learning.

PBL was definitely not my style of learning. I was really frustrated that teacher did not give out information in a structured manner. It seemed I was lost.

There are too many issues to discuss. I and other team members don't have enough knowledge background. There are too many things left out for us to find out on our own. I even didn't know where to begin.

3) From the observer's field notes

The PBL lesson presented in this study was, in the aspects of contents, process, products, teachers' variables, observed for four times intensively by an expert in the area of gifted education and problem based learning. Items pre-

sented in **Table 1** above were used as the major basis of the observation. One of the most attractive aspects of PBL for students is that teaching and learning are done in the spirit of research, as **Birch (1986)** indicated. Other unique character of the PBL has included student-centered lesson in which each student could participate actively. Most of all students were motivated intrinsically, had responsibility for their learning process, and had interest on it because they conducted the lesson by themselves in the way of selecting, designing and devising. Besides, higher level of thinking skills and creative problem-solving ability were facilitated through the increase of interaction between teacher-student, development of effective communication skills, and improvement of responsibility as a team member, and various questions and discussion. Through such type of learning method, students could experience 'science' on their own and improve the quality as a pre-scientist. Also, the unique points of the PBL lesson presented through the observation are the followings:

- Individual differences in a lesson can be considered actively. That is, it gives learners a chance to optimize the learning level of each learner.
- Rather than simple memorizing knowledge, critical, creative thinking ability and problem-solving ability are emphasized.
- Learners can meet with more various information.
- It is learning for actual understanding rather than learning for grades.
- Leadership is cultivated.
- Confidence of complex problem-solving can be formed.
- The ability to solve problems, generalize the results, and present them is cultivated.
- Learners are encouraged to build up an appropriate lesson goal for them.
- They learn the way to search for useful help by themselves.
- They can analyze and evaluate each achievement by themselves.
- They can analyze and evaluate their peers' achievements.
- Tenacity for project is increased.
- Through participating in entire class discussion, each result and critical analysis is presented.

In addition to these, several aspects observed in the study should be discussed more concretely in applying the program. The first thing is teacher variation. Even though teachers consider them experts in their field, they do not much think about his role as a guide or facilitator in the classroom. Unlike lecture-like lessons, in the problem-based learning teachers' special roles and qualities are required. Teachers as facilitator should listen to students' opinions carefully, encourage them to solve the problems by themselves, monitor the state of group activities effectively, recognize the time when intervening and the vice versa, encourage students to comprehend scientific concepts correctly, acknowledge teachers' ignorance about unknown parts, give proper feedback, and solve the conflict between teachers and students or students and students. Teachers should encourage students to lead the lesson by themselves. Such qualities of teachers play a determined role in the efficient management of the problem-

based learning. Suppose that excellent programs are developed, however, if there are not teachers who carry out them, the programs cannot be managed appropriately. In particular, unlike in general science education, teachers' creativity and creative instruction are required much more in science-gifted education. Besides, teachers' training and education based on constructivism and thorough programs are required as urgent as the development of curriculums.

The second is related to student variables. It is possible that students are silent and make no response or rush about to no purpose because they are not accustomed to learning in such way. In particular, it was shown that students had a lack of the ability to understand the result, and interpret and organize it, or ask questions and raise objections. Proper work-assignment and lecturing for essential background knowledge are necessary. Helping them to set their goals and giving instructions for struggling students or teams are essential in the beginning. Besides, it is needed that students have an opportunity to reflect and evaluate their own products after the lesson. If students were to experience PBL in group more frequently, then this would not be such an issue because these skills would be built up over time.

Third, the problem-based learning is the possibility toward learning that can consider individual variations for the gifted children. Students' reaction and interaction, which can be observed through the problem-based investigation lesson type, is the qualitatively different important result, which does not be gotten from the teacher-centered lecture type of lesson. PBL gives an important opportunity to understand a student's ability and interests or learning styles, and it is important since the individualization of programs for each gifted child and consideration about individual variation are much required.

Fourth, usefulness of appropriate materials and easiness of use is very important to solve problems. However, because basic materials and related documents, and Internet access were not accomplished without difficulty, it was problematic to apply PBL type of lesson appropriately in the present study. The absence of tools and instruments of high-quality should be solved.

5. Conclusion

Even though teachers can teach students the procedural knowledge about what and how they can investigate in the existing classrooms, the true essence that we had missed was doing science. In particular, such demand and need were shown in brilliant children in science fields, but the appropriate programs and their effectiveness were rarely developed and examined. Faced with such problems, this study explores the PBL approach with gifted students. Introduction of PBL has resulted in significant changes to the way in which teaching and learning are viewed and offers exciting possibilities for learning-teaching practices for gifted students.

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