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Collaborative Action Research: A Case in Korean Earth Science Classrooms

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Abstract: This study is a report of the collaborative action research which has been conducted between a Korean earth science teacher and science education researcher. A two-year long action research effort was made in order to improve the teacher's earth science classrooms in pursuit of constructivist principles of learning. The process of the action research was described with the aim of increasing the awareness of science teachers and science education researchers regarding action research. Quantitative evidence was presented to indicate the effectiveness of the collaborative action research in creating constructivist learning environments in the classrooms. The process and quantitative evidence from the action research permitted a consideration of implications for future efforts to improve science classrooms.

Keywords: action research, constructivist principles, Korean earth science classrooms

Introduction

People often note the gap between educational theories and practices: educational theories have been presented with little practical application suggested and failed to help teachers deal with their immediate needs within their own classrooms (Hurd, 1991; Korthagen & Kessels, 1999; Kyle & Shymansky, 1988; Richardson, 1994). The theory-practice gap also means that research findings, when applied in actual classroom settings, result in unexpected outcomes which are different from what was originally predicted. According to Eisner (2002), educational research has typically been conducted with the 'true experimental' method in which experimental and control groups are matched and all confounding sources are controlled. Although such conditions could be achieved in the experiment, they are unlikely to be replicated in actual classrooms since the classroom reality is complex and unpredictable.

The theory-practice gap is at times regarded as an obstacle to educational reform. Educational reform efforts are usually based on the myth that schools and classrooms can be improved by simply disseminating a new curriculum or pedagogical knowledge and leaving it up to teachers to put them into practice. Under this assumption, teachers are viewed as technicians who are expected to receive the knowledge of professional researchers and apply it in the context of practice that have been ignored in the research process (Cochran-Smith & Lytle, 1993; Lieberman, 1992). Consequently, the history of reform is one of consistent failure in meeting major goals of educational improvement (Pogrow, 1996).

Given this, action research arises as a promising way to bridge the gap between educational theory and practice and to realize improved practices in schools and classrooms. Action research is "a form of collective self-reflective [i]nquiry undertaken by participants in social situations" (Kemmis & McTaggart, 1988, p. 5). It allows teachers to focus on practical problems, reflect on their own practices, take actions, and revise the actions on an ongoing basis to bring about targeted improvement. Action research is by nature a collaborative effort among participants with a shared concern (Corey, 1953; Kemmis & McTag-

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gart, 1988; Kyle & Hovda, 1987; Whitford et al., 1987). Collaborating partners may be teachers, students, principals, and other community members, but in most instances they are teacher practitioners and professional researchers.

A two year-long action research has recently been completed through collaboration between a Korean earth science teacher, Mr. Park (a pseudonym) and science education researcher (called the "collaborating researcher" in this study). This study as a report of the collaborative action research provides a description of the action research process and its quantitative outcomes. Thus, the study was intended to increase the awareness of science teachers and science education researchers regarding action research and to indicate the effectiveness of the action research in creating constructivist learning environments in Korean earth science classrooms.

The Process of the Collaborative Action Research Implemented

According to Kemmis and McTaggart (1988), action research begins with the identification of educational concerns that a teacher has and proceeds on spirally recurring cycles of four phases: planning, action, observation, and reflection. The action research addressed in this study followed a similar process to the Kemmis and McTaggart's description as Mr. Park and the collaborating researcher worked together with each other. The subsections below provided explanations of each phase of the action research process undertaken.

Context of the collaborative action research

Mr. Park was an earth science teacher in a high school located in a mid-sized city, Korea. He participated in a science teacher inservice workshop which was held at the University of Iowa in summer, 2000, and was committed to conducting action research projects as a follow-up program of the 2000 workshop. The 2000 Iowa program was designed to stimulate and support the participating teachers to improve their classroom practices through studying and practicing innovative approaches to science teaching and learning. In the summer workshop, the teacher enrollees were provided with opportunities to study how people learn based on constructivist perspectives, experience new earth science curricula in the U.S., exchange teaching expertise with local science teachers, participate in field trips to geological sites, develop earth science instructional modules and apply them in micro-teaching situations. After the workshop, the Korean teachers were involved in follow-up programs on the basis of their voluntarism, in which they were encouraged to conduct classroom action research in collaboration with the research staff at the University of Iowa.

Until he participated in the 2000 Iowa workshop, Mr. Park had been teaching earth science for 11 years in North City (a pseudonym) which is about one hour-drive away from Seoul, the capital city of Korea. Thanks to its location, North City suffers a problem that most satellite cities have in common: many high-achieving students move into larger cities (e.g., Seoul) where they believe that they will be better prepared for the college entrance examination, and the "filtered" students are left to study in high schools of North City. When interviewed, Mr. Park revealed a difficulty in engaging his students in scientific inquiry by saying, "It would be more exciting if I did this [student inquiry] in a different place such as a science magnet school." Despite such a difficulty, Mr. Park believed that student-centered, inquiry-oriented methods could improve science teaching and learning in his earth science classrooms. According to him, that is especially because "Earth science can provide students with first-hand experiences with the natural phenomena." Hence, Mr. Park was readily convinced of the merits of the innovative approaches to which he had been exposed through the summer workshop. Also, at the end of the workshop, he responded that he became to have more interest in student inquiry and agreed to collaborate on action research with the science education researcher at the University of Iowa.

Identification of Mr. Park's educational concern

The collaborative action research was initiated when Mr. Park and the collaborating researcher discussed with each other, focusing on educational concerns about the teacher's own science classrooms. Mr. Park's primary concern was that his students were "ignorant of how to learn" when both cognitive and communicative aspects of learning were considered. He indicated, "My students have no idea of how to communicate what they know even though they know a lot. More seriously, they do not know how to think." When these concerns and problems were uncovered, Mr. Park expressed strong commitment for collaborating on action research in order to improve his science classrooms. What the action research should achieve was also identified by the teacher himself. Mr. Park said:

> So far I have thought that our classes are governed by teacher direct instruction with no consideration for student opinions (e.g., what they want to learn). This is true even in doing lab activities. It is one of the important goals of this class to foster *logical thinking* and *the ability to communicate one's own ideas*. For this purpose, the teacher needs to talk less and to encourage students to talk more. The teacher should remind students that it is students who are the master of the class so that they can play a leading role for the class.

Further discussions with Mr. Park revealed what he meant by "logical thinking" and "the ability to communicate." Mr. Park acknowledged that his word "logic" was compatible with 'scientific' and proceeded to say, "In science classrooms, students need participate in such practices as identifying what they wonder about, seeking evidence and arguing with the evidence, and discussing [what they found] with their friends." It was believed that ongoing participation in such practices would allow students' use of scientific inquiry and discourse for their learning and therefore result in the improvement of Mr. Park's earth science classrooms.

Choosing constructivist principles as a referent

It did not take long for Mr. Park to find that his ideas had many things in common with constructivist principles of learning. Consequently, the constructivist principles became a referent for Mr. Park's action research. Although various forms of constructivism have been developed (c.f., Confrey, 1995; Ernest 1994; Geelan, 1997; O'Connor, 1998; Perkins, 1999; Phillips, 1995), the teacher and collaborating researcher found that the principles developed by Duffy and his colleagues (Barab & Duffy, 2000; Duffy & Cunningham, 1996; Duffy & Orrill, 2001; Honebein et al., 1993; Savery & Duffy, 1996) were the most congruent with Mr. Park's educational vision for his own earth science classrooms.

First, according to the constructivist principles, learning is situated and therefore needs to be anchored in an authentic context. An authentic learning context refers to "environments that are consistent with contexts we expect the student to be able to work in after the course is over" (Duffy & Orrill, 2001, p. 2). If science education is to develop scientific literacy in students, learning should be centered on student activities which present the same type of cognitive and discursive practices of scientists (National Research Council [NRC], 1996).

Second, learning is goal-driven. It is driven by an individual's need to understand and achieve some goals. This principle implies that students should engage in the inquiry process of their own. There are three components to this engagement: the students 1) must see the problem as important and personally relevant, 2) feel that their action is of value and not just an exercise, and 3) have decision-making responsibility.

Third and lastly, the constructivist principles indicate that learning is inherently social-dialogical. Knowledge is based on social negotiation and evolves through interactions with others. Working together provides opportunities to articulate one's view and to hear evidence that supports or contradicts the view. From this perspective, constructivists have consistently stressed interactions within classroom participants.

Thus, the collaborative action research between Mr. Park and the science education researcher began with a view to improving the teacher's earth science classrooms in pursuit of the constructivist principles of learning. The action research continued when the cyclic process of planning, action, observation, and reflection was followed repeatedly during a two-year long period.

Planning phase

Planning was the phase of the action research in which instruction methods were designed for improving Mr. Park's earth science classrooms. When the general instructional method was to decided on for Mr. Park's action research, it was considered most importantly that the instructional method should be able to afford opportunities for students to experience various ways of doing scientific inquiry as they attempted to resolve their own curiosity. Therefore, a method which was mainly concerned with student acquisition of predetermined scientific knowledge was not likely to be chosen. As a result, the Group Investigation (GI) method was determined as the most feasible for the action research since its protocol could provide learners with very broad and diverse experiences of scientific inquiry (Kagan, 1985; Sharan & Sharan, 1989, 1994). In Mr. Park's action research classrooms, the GI method was implemented in the following order: 1) *In-class Discussion*, in which students were organized in small research groups to plan their own projects, 2) *Out-of-class Investigation*, in which each group carried out its investigation, and 3) *In-class Presentation*, in which students presented their findings and discussed them with others.

The planning phase was also the moment in which teaching and learning strategies were specified to guide Mr. Park and his students in implementing GI. Several strategic decisions were made as a result of discussions between the teacher and collaborating researcher. Examples of the important strategies decided included students keeping science journals and using them throughout the GI process, the teacher providing examples of problems to be studied through investigations, and students engaging in peer assessment. Such strategies were employed complementarily to the general instructional method so that the learners could have more ownership and responsibility for their learning (see, for more information about the specific strategies used, Oh & Shin, in press, and Oh et al., 2004).

Action and Observation phases

Action meant implementation of the GI method in Mr. Park's earth science classrooms. This was also the moment in which the teacher and students used the strategies proposed in the planning phase to learn earth science through GI. In Mr. Park's earth science classrooms, the GI method and other complementary strategies were implemented as two action research projects titled the year 1 and year 2 projects were undertaken. The year 1 project proceeded from March, 2001 to February, 2002 as two 11th grade earth science classes were involved. During this period, GI was employed three times as parts of the study of three earth science units. As a result of reflection on the year 1 project, the year 2 project was enacted at March, 2002 through February, 2003 with two other 11th grade earth sci-

Table 1. Classes Involved in the Action Research Projects

Project	Number of classes involved	Code of the class	Number of students		
			Males	Females	Total
Year 1	2	1A	28	8	36
		1B	26	9	35
Year 2	2	2A	27	6	33
		2B	28	4	32

ence classes involved. The year 2 project included five times for implementation of the GI method. The time spent on each GI implementation was varied, but normally, one class hour (50 min.) was devoted for in-class discussion and two or three class hours for in-class presentation. However, since the teacher and students had to invest much more time on out-of-class investigations, it took 3 or 4 weeks to complete all the activities for GI for a given unit.

Information about the classes involved is presented in Table 1. The students enrolled in the classes were all those who were on the science track and planned to major in science-related areas in college. Each of the four classes met three days per week to study earth science with Mr. Park. The classes were heterogeneously grouped, which meant that students academic achievement in a class was varied across all ranges. Further, according to Mr. Park, there was no difference between the two classes involved in each action research project (i.e., classes 1A and 1B in the year 1 project and classes 2A and 2B in the second) in terms of student performance on school-wide semester tests.

While the GI method was carried out in the action research classrooms, Mr. Park and the collaborating researcher engaged in *observation* in different ways. That is, Mr. Park conducted "complete-participant observation" (Spradley, 1980), where he guided students in engaging in their own learning activities and identified new concerns about science teaching and learning. At the same time, Mr. Park made parts of the in-class activities recorded on videotapes by setting up video recording equipments in front of and/or at the end of the class. The videotapes were then sent to the collaborating researcher so that he could analyze them and prepare feedback for the teacher. Thus, although observations had different meanings for the teacher and researcher, such direct and indirect observations together provided a sound basis for reflection concerning educational practices in Mr. Park's action research classrooms.

Reflection phase

Reflection was the phase for critical and constructive reviews of teaching and learning practices in Mr. Park's earth science classrooms. The reflection was initiated when the teacher received feedback about the videotaped classroom activities and discussed relevant issues with the collaborating researcher. It was not an assumption underlying the action research projects that a particular instructional method automatically entails improved classroom practices. Rather, the projects were based on the perception that improvement of classroom practices depends on the teacher's and students' judgments of a classroom situation and their actions regarding that situation. Therefore, the teacher-researcher discussions in the reflection phase were usually centered on issues of what could have been done in a certain moment and how it could be repeated in similar situations. For instance, it was observed through the video recordings that the teacher often addressed student misconceptions in a rather long monologue. In such a case, the researcher provided some forms of genuine dialogues (c.f., Oh et al., 2003) that the teacher and students could utilize for jointly reformulating the concepts as more scientifically accurate. Thus, the reflection phase was always accompanied with new teaching skills and strategies, which were in turn carried over into the next action research step.

A reflection phase called for another planning phase, where a new action research cycle of planning-action-observation-reflection would begin. Such an iterative process continued until a year-long action research project was completed. Further, the second year action research project, i.e., the year 2 project was launched as a continuation of the year 1 project when its general plan was made from reflections on the previous experiences of implementation of the GI method in Mr. Park's classrooms. The year 2 project also proceeded in the same way that followed the action research cycle repeatedly.

Presentation of Quantitative Evidence

Collecting quantitative data

In the course of the action research, multiple types of data were gathered in order to determine the effectiveness of the action research effort. Out of these, the Constructivist Learning Environmental Survey (CLES, Taylor et al., 1997) was an instrument used for collecting quantitative evidence to monitor the development of constructivist learning environments in Mr. Park's earth science classrooms. The CLES measures student perceptions of their classrooms through five subscales which correspond to key aspects of constructivist learning environments: Personal Relevancy (PR), Student Negotiation (SN), Shared Control (SC), Critial Voice (CV), and Scientific Uncertainty (SU). Each subscale contains six items to which students are supposed to respond with a five-point scale.

A Korean-translated version of the CLES was administered to Mr. Park's students in March when a new action research project began, and it was repeated at the end of the first and second semesters. This procedure yielded three temporal subsets of student responses to the CLES: initial, interim, and final sets. In general, the internal consistency reliability of each CLES subscale was greater than .70 when Chronbach alpha (α) coefficient was used.

Analysis method

Given the quantitative data, descriptive statistics, i.e., mean and standard deviation, were computed for each subscale of the CLES. Statistical analysis was then carried out using the repeated measures analysis of variance (ANOVA) method to determine the presence of significant change in student perceptions over time. That is, the repeated measures ANOVA was applied to compare the mean scores of the three temporal sets - initial, interim, and final sets of each subscale of the CLES at the .05 and .01 levels. Whenever relevant, Tukey's Honestly Significantly Difference (HSD) post-hoc tests were implemented to check the reason for the significant change. For the post-hoc test, the Q-distribution was used when the Q-value was computed using the following formula:

$$Q = \frac{\Delta M}{\sqrt{MSE/n}}$$

ΔM = mean difference
MSE = mean square error
n = number of students

The analysis was carried out for each class involved in the action research projects. However, since it was not a purpose of the action research to discriminate between the classes, statistical comparisons were not applied.

Results of the analysis

Table 2 presents a summary of descriptive statistics and results of the repeated measures ANOVA for the CLES data. Generally it is indicated that the collaborative action research was successful in creating constructivist science learning environments in Mr. Park's earth science classrooms. The results for each subscale of the CLES are described below.

Table 2. Summary of Statistics for the Subscales of the CLES

Project year	Class (N)	Mean (S.D.)			F	p
		Initial	Interim	Final		
Personal Relevancy (PR)						
Year 1	1A (31)	2.84 (.71)	2.88 (.87)	3.00 (.59)	F (2, 60) = 1.19	.311
	1B (32)	2.47 (.74)	2.73 (.61)	2.91 (.74)	F (1.63, 50.61)^{a} = 7.57**	.003
Year 2	2A (30)	2.91 (.57)	3.13 (.62)	3.58 (.65)	F (2, 58) = 12.74**	.000
	2B (30)	2.91 (.83)	3.00 (.71)	3.24 (.58)	F (2, 58) = 4.97*	.010
Student Negotiation (SN)						
Year 1	1A (31)	2.52 (.58)	3.13 (.81)	3.13 (.68)	F (1.66, 49.69)^{a} = 13.40**	.000
	1B (32)	2.05 (.53)	2.80 (.73)	2.81 (.63)	F (2, 62) = 30.05**	.000
Year 2	2A (30)	2.74 (.47)	2.99 (.56)	3.17 (.61)	F (2, 58) = 6.87**	.002
	2B (29)	2.79 (.60)	3.03 (.73)	3.18 (.62)	F (2, 56) = 6.80**	.002
Shared Control (SC)						
Year 1	1A (31)	2.12 (.62)	2.34 (.63)	2.56 (.58)	F (2, 60) = 9.91**	.000
	1B (32)	1.72 (.55)	2.23 (.64)	2.40 (.62)	F (2, 62) = 23.44**	.000
Year 2	2A (30)	2.35 (.69)	2.67 (.74)	2.72 (.71)	F (2, 58) = 4.18*	.020
	2B (30)	2.09 (.62)	2.31 (.72)	2.53 (.66)	F (2, 58) = 9.36**	.000
Critical Voice (CV)						
Year 1	1A (31)	2.26 (.62)	2.63 (.65)	2.42 (.56)	F (2, 60) = 5.77**	.005
	1B (32)	2.03 (.61)	2.35 (.67)	2.46 (.59)	F (2, 62) = 6.43**	.003
Year 2	2A (29)	2.36 (.57)	2.56 (.63)	2.73 (.51)	F (2, 56) = 5.30**	.008
	2B (30)	2.33 (.32)	2.32 (.52)	2.33 (.56)	F (2, 58) = .005	.995
Scientific Uncertainty (SU)						
Year 1	1A (31)	3.05 (.50)	2.96 (.54)	2.90 (.52)	F (1.70, 51.07)^{a} = 1.05	.349
	1B (32)	2.60 (.55)	2.84 (.50)	2.83 (.56)	F (2, 62) = 2.96	.059
Year 2	2A (30)	2.83 (.47)	2.88 (.47)	3.02 (.51)	F (2, 58) = 3.30*	.044
	2B (30)	2.87 (.55)	2.82 (.54)	2.86 (.47)	F (2, 58) = .19	.826

^{a}The degree of freedom is adjusted since the sphericity assumption was violated.
*$p < .05$, **$p < .01$

The PR is the subscale of the CLES that assesses students' perceptions of the connectedness of learning school science to their out-of-school lives. The statistical outcomes for the perceptions of Mr. Park's students concerning this scale indicated that as the action research proceeded, the students considered science learning increasingly relevant to their everyday experiences. Statistically significant changes were found in classes 1B, 2A, and 2B. According to the post-hoc tests, for classes 1B and 2B significant changes existed between initial and final periods of the action research (Q = 4.94 and 4.30 for 1B and 2B, respectively, $p < .01$). For class 2A, mean differences were statistically significant between interim and final periods (Q = 4.68, $p < .01$) as well as between initial and final ones (Q = 7.01, $p < .01$).

The SN scale examines to what extent students explain and justify their thoughts, listen and reflect on other students' ideas, and look critically into their own thinking. Table 2 shows that student perceptions of Mr. Park's science classrooms with regard to providing opportunities for SN increased statistically significantly in all the four classes over time. The post-hoc test revealed that for classes 1A and 1B, significant improvement occurred both between initial and interim periods (Q = 5.76 and 9.40 for 1A and 1B, respectively, $p < .01$) and between initial and final ones (Q = 5.76 and 9.59, $p < .01$). For classes 2A and 2B, it appeared between initial and final periods (Q = 5.22 and 5.17 for 2A and 2B, respectively, $p < .01$).

The SC subscale is associated with student ownership and responsibility about their learning. This scale measures the degree to which students collaborate with the teacher to create and manage a constructivist learning environment. In Mr. Park's action research classrooms, student perceptions about SC developed in a positive direction, and this pattern of change proved to be statistically significant. Based on the post-hoc tests, mean differences were statistically significant between initial and final periods for classes 1A, 2A, and 2B ($Q = 6.30$, $p < .01$ for 1A, $Q = 3.77$, $p < .05$ for 2A, and $Q = 6.11$, $p < .01$ for 2B) while class 1B saw the improvement both between initial and interim periods ($Q = 7.00$, $p < .01$) and between initial and final ones ($Q = 9.29$, $p < .01$).

The CV subscale is concerned with the relationship between the teacher and students. This scale measures the extent to which a social climate has been established in which students feel that it is legitimate and beneficial to question the teacher's pedagogy and to express concerns about any impediments to their learning. The statistical outcomes confirmed that student perceptions of CV improved in statistically significant ways in three of Mr. Park's earth science classes. For class 1A, the significant change occurred between initial and interim periods ($Q = 4.79$, $p < .01$). Although the final mean score was lower than that of the interim period, there was no statistically significant difference between the two values. In the case of class 1B, mean differences were found statistically significant both between initial and interim periods ($Q = 3.66$, $p < .05$) and between initial and final ones ($Q = 4.87$, $p < .01$). For class 2A, the improvement in student perceptions of CV was observed between initial and final periods of the action research ($Q = 4.60$, $p < .01$).

The SU subscale reflects the constructive nature of scientific knowledge. It assesses the extent to which opportunities are provided to perceive scientific knowledge as arising from an ongoing changing enterprise that has been influenced by human values and developed in socio-cultural contexts. There was the least improvement in the perception of Mr. Park's students regarding SU. That is, a statistically significant change was found only for class 2A, and this change appeared between initial and final periods ($Q = 3.50$, $p < .05$).

Discussion

Action research in science education

There are several researchers in science education who use action research in contexts as diverse as curriculum development, teacher preparation programs, and inservice education (Cheng et al., 1998; Feldman, 1996; Hodson & Beneze, 1998; Pedretti & Hodson, 1995; Tabachnick & Zeichner, 1999). Among these, Hodson and Beneze's (1998) study is worth noting in that it provides a model of how classroom teachers and professional researchers work together through action research. In a project for effective curriculum practices, the teachers' duties included ongoing reflection and challenge of each other's beliefs and practices while seeking alternatives and using them in developing new approaches. The researchers served the teachers as facilitators by reviewing curriculum materials, observing lessons, and reflecting the teachers' understanding and practices. In particular, the researchers' role of providing impetus for teachers to change their views and practices was crucial in the collaborative process. In the action research addressed in this study, the relationship between Mr. Park and the collaborating researcher was basically that of practitioner and facilitator, which was similar to what Hodson and Beneze (1998) illustrated by means of their project. This role model should also be established in the field of science education in order that science education research can contribute to the improvement in science classrooms. Action research can provide an opportunity to build such relationships while teachers and researchers collaborate for the shared goal of improved educational practices.

Action research can be included in a professional development program for science teachers (e.g., Cheng et al., 1998). For example, the Iowa Chautauqua Program (ICP) is a science teacher professional development program which advocates collaboration between teachers and researchers and/or among teachers as a key component of the program (Dass, 1996; Shin & Oh, 2003). Actually, it often occurred that as ICP participants shared their experiences with classroom action research and reported successes, that called for new workshops and other forms of teacher involvement. Thus, the ICP provides a model of how a teacher education program can include action research projects in which practicing teachers assume a leading role in bringing about real changes in science classrooms. If teachers are to be sources for their own professional growth and classroom improvement (NRC, 1996), such models as the ICP should be considered in the context of science teacher education.

Development of constructivist science classrooms

As Mr. Park was, teachers of science who are anxious to improve their traditional classrooms may be inspired by constructivist principles of learning. To create a constructivist science classroom, learning should occur in ways that are relevant to students (Duffy & Cunningham, 1996; Duffy & Orrill, 2001; Talyor et al., 1997). It can be achieved by use of student experiences as a meaningful context for learning. That is, students should be allowed to set learning goals from their own curiosity and pursue them through inquiry-based approaches such as the GI method used in Mr. Park's action research classrooms. The emphasis on relevancy is based on the assumption that learning always takes place in a context and the context in turn affects the nature of learning. This is a reason constructivists argue for authentic learning environments. However, as Honebein et al. (1993) pointed out, "Authentic activity is a relative concept." That is,

> If we want to our student to excel on tests, then the authentic activity is to focus on test taking behaviors. The purpose the learner brings to the task is that of passing a test. Hence, learning is focused on organizing and storing information in such a way that can be retrieved for a test (Honebein et al., 1993, p. 89).

By contrast, if a goal of science education is to develop scientific literacy in students (NRC, 1996), authentic science learning environments are those in which students have opportunities to participate in scientific inquiry and discourse for solving their own problems. Thus, it is necessary that to create a desired learning environment, the teacher and students develop shared goals concerning the improvement of their classroom practices.

From the constructivist perspective, students should be involved in a significant way with developing their own learning environments. This claim goes beyond simply adding student ideas to teachers' repertories for planning a lesson. It suggests that students should have ownership and responsibility of their learning by collaborating with the teacher to share control of all aspects of developing a learning environment, such as the articulation of learning goals, the planning and management of learning activities, and the determination and application of assessment criteria. It also implies that students are able to exercise legitimately critical voices about how their learning activities occur (Aldridge et al., 2000; Taylor et al., 1997). While learning through the GI method in the action research classrooms, Mr. Park's students experienced such ownership and responsibility; they decided what they would investigate, how they were going to carry out inquiries, and how they would present their findings. As a result, Mr. Park's action research classes saw that the levels of student perceptions regarding shared control and critical voice increased over time.

Teachers often express a dilemma regarding sharing control with students, such as how much control should be given to students. Facing this problem, some teachers may offer opportunities for students to contribute while continuing to set most of the task for themselves because they fear that the class might end with chaos (c.f., Johnson, 2000). There can be others who combine constructivist teaching strategies with traditional activities without much recognition of the conflicts between the two approaches (c.f., Windschitl, 2002). Such eclectic teaching practices might be a beginning of a classroom reform effort. However, those practices should be reviewed on a continuous basis so that new strategies can emerge to move the classroom in desired directions. Action research is believed to provide a model of such ongoing reflection and improvement processes.

Conclusion

This study described the process of the action research which was conducted in Korean earth science classrooms through collaboration between a secondary science teacher and science education researcher. It also presented the quantitative evidence which indicated that the collaborative action research was successful in improving science classrooms as more constructivist. Based on the process and quantitative evidence of the action research, general conclusions are presented to provide implications for future efforts to improve science classrooms. Action research can provide teachers with an opportunity to realize improved educational practices in their classrooms. It can also help teachers' professional growth because, while participating in the action research process, teachers can build on their own knowledge and skills by critically examining their professional behaviors and finding better pedagogical practices. In particular, teachers may gain far more benefit from collaboration with professional researchers since "sometimes we [teachers] are so close to a subject or an activity we can scarcely see it" (Hobson, 2001, p. 7). Today's reform efforts in science education views teacher as being at the heart of the envisioned future of science education (NRC, 1996). Changes in teacher practices through action research are believed to provide a pathway to sustainable improvement in science classrooms which in turn leads to real reform in science education.

As evidenced by Mr. Park's action research, the constructivist perspectives of learning can serve teachers as a referent to improve their classrooms. Science teachers with a desire to change their classroom practices in line with constructivist principles should prepare themselves to make an appropriate use of inquiry-oriented methods like GI. Specifically, such methods ought to be applied in ways that emphasize student ownership and responsibility of learning and prompt collaboration and communication among students. It should also be noted, however, that although the development of constructivist science classrooms is highly dependent on interactions among students, this principle does not entail lessoning of the teacher's pedagogical responsibility to guide students in the learning process (Applefield et al., 2001). Therefore, teachers must be able to make careful judgement about classroom situations and realize timely interventions to facilitate student learning of science. Further studies are needed to identify how science teachers fulfill such pedagogical roles in science classrooms.

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