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Development of Constructivist Science Classrooms and Changes in Student Attitudes toward Science Learning

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ABSTRACT *Previous studies implied that the development of a constructivist-learning environment could contribute positively to changing student attitudes toward science learning. However, little research has been conducted to examine such an association over time. This study was designed to investigate the relationships between the development of constructivist science classrooms and changes in student feelings about science lessons by using longitudinal data collected from two action research projects. Statistical analyses showed that the degree of positive student attitudes toward science learning increased as their science classrooms became more constructivist. Further, out of five elements of a constructivist-learning environment, Personal Relevancy (PR) was the most significant component for explaining the positive changes in student attitudes. This study identified, among other educational models, Problem-Based Learning (PBL) and Project-Based Science (PBS) as two instructional approaches, which can be used in science classrooms for promoting the relevancy of instruction*

KEY WORDS: *constructivist-learning environment, student attitudes toward science learning, Problem-Based Learning/Project-Based Science*

Introduction

Constructivism has evolved as one of the prominent learning theories in the broad field of education. A constructivist approach pursues an authentic learning environment in which students are actively engaged in their own inquiries into problems relevant to them; it stresses communication and collaboration of students with their peers as well as with the teacher (Duffy & Cunningham, 1996; Savery & Duffy, 1996). This constructivist portrayal is congruent with the feature of the science classroom envisioned by major science education reform movements, which emphasize inquiry as the principle of science teaching and learning in pursuit of scientific literacy for all students (American Association for the Advancement of Science [AAAS], 1990; National Research Council [NRC], 1996). Indeed, constructivism can serve as a referent for curriculum practices in reform-oriented science classrooms (Tobin & Tippins, 1993).

In science education, an enduring problem is that student attitudes toward science learning become more negative as students progress through the K-12 grades and between the beginning and end of the school year while enrolled in science courses (Butler, 1999; Koballa, 1995; Yager & Penick, 1986). Previous studies have revealed, however, that while relatively negative feelings of students are usually associated with more traditional approaches to science instruction (Lord, 1997; Shepardson & Pizzini, 1993), their perceptions of science classrooms as constructivist are correlated positively to student attitudes (Aldridge et al., 2000; Fisher & Kim, 1999; Hand et al., 1997). Therefore, it is believed that the development of constructivist learning environments in science classrooms will increase positive student attitudes toward science learning in school. This study was conceived as a means to provide empirical evidence for this claim by examining the relationships between the development of constructivist science classrooms and changes in student attitudes over time.

Background

Attitudes are defined as "general and enduring positive or negative feelings" (Koballa & Crawley, 1985, p.223), and they are regarded as outcomes, which can be acquired over the process of learning. Since Bloom and his colleagues suggested a taxonomy which involved affective outcomes as a domain of educational objectives (Krathwohl et al., 1964), positive student attitudes have constituted part of the goals to be achieved as a result of teaching and learning in school (AAAS, 1990; NRC, 1996; Yager & McCormack, 1989). However, students will not acquire positive feelings about science simply because they are taught more scientific information. In order to foster such affective outcomes, a learning environment should be designed in ways that ensure the development of students' positive attitudes as well as their attainment of scientific knowledge (Koballa & Crawley, 1985).

Student attitudes, as considered together with appropriate situational variables such as teachers, facilities, and peers, are closely linked to the students' behaviors regarding learning (Koballa, 1995). In all classrooms, students are continuously making a choice: they may choose to engage in learning activities or to disengage (Starnes & Paris, 2000). If they held more favorable attitudes about the subject matter taught, they are more likely to decide to learn and education can occur more smoothly and actively. Further, positive feelings toward science "leads to a positive commitment to science that influences lifelong interest and learning in science" (Simpson & Oliver, 1990, p.14). This is a reason major science education reform efforts have put an emphasis on the improvement of student attitudes. For instance, *Project 2061* as a multiple year project in science education suggests "science education should contribute to ... the development in young people of positive attitudes toward learning science" (AAAS, 1990, p. 184).

Research has indicated the positive correlation between constructivist classroom environments and student attitudes toward science. Aldridge et al. (2000) investigated the relationships between five dimensions of a constructivist-learning environment and student attitudes by using the Constructivist Learning Environment Survey (CLES) (Taylor et al., 1997) and an eight-item scale based on the Test of Science Related Attitudes (TOSRA) (Fraser, 1981). Fisher and Kim (1999) also used a TOSRA-based attitude scale and the CLES instrument for Korean students with the same research purpose. These two studies were parallel in that they uncovered positive relationships between students' perceptions of constructivist learning environments and their attitudes toward science lessons.

Specifically, out of the five constructivist elements defined in the CLES, Personal Relevancy (PR), Student Negotiation (SN), and Shared Control (SC) were the most significant predictors for positive student attitudes. This research finding provided a good reason for believing that the development of a constructivist science-learning environment can contribute to changing student attitudes toward science learning in a positive direction.

Nevertheless, few studies have examined the associations between the development of constructivist classrooms and changes in student attitudes over time. Therefore, the goal of this study was to investigate such associations by using longitudinal data concerning students' perceptions of and attitudes toward science classes throughout an academic year. In particular, the present study addresses which element(s) of a constructivist learning environment accounts more significantly than others for a change in student attitudes over the period of a whole year.

Methodology

Sample

This study is part of an ongoing report about classroom action research, which was undertaken in a Korean high school over two academic years. The primary goal of the action research was to create constructivist-learning environments in the 11th grade earth science classrooms. To attain this goal, a modified Group Investigation (GI) method was implemented. GI was a collaborative learning process in which students were organized into small research groups and inquired into topics arising from their own questions. In addition, during the second project year, peer assessment was enacted among students with a view to incorporate more constructivist feature in the action research classrooms (see, for more information of the action research projects, Oh et al., 2003, in press; Oh & Shin, 2004). As many as 71 students from two classes participated in the first action research project (Year 1 project, 2001-2002 academic year) and 65 from two other classes in the second one (Year 2 project, 2002-2003 academic year). A survey procedure repeated three times each year for these students provided data for this study.

Instruments and collecting data

In the action research process, the CLES was used three times to gain longitudinal data for student perceptions of their science classrooms. In other words, student perceptions of their science classrooms were used as indicators of how the classrooms moved toward constructivist learning environments. The CLES instrument involves five subscales that comprise constructivist classroom elements. These are (c.f., Aldridge et al., 2000; Taylor et al., 1997):

- *Personal Relevancy* (PR) is the scale measuring the connectedness of school science to students' out-of-school lives with making use of students' everyday experience as a context for learning science. An example of the items in this scale is "My new learning starts with problems about the world outside of school."
- *Student Negotiation* (SN) assesses the extent to which students explain and justify to others their newly developing ideas and listen and reflect on the viability of other students' ideas. The items in this scale include, "I talk with other students about how to solve problems."

- *Shared Control* (SC) measures the degree to which students share with the teacher control for developing a learning environment. Items include "I help the teacher to plan what I am going to learn" and "I help the teacher to assess my learning."
- *Critical Voice* (CV) examines the extent to which social climate has been established where students feel that it is legitimate and beneficial to question the teacher's pedagogical plans and methods and to express concerns about any impediments to their learning. An example of the items in this scale is "It is OK for me to question the way I am being taught."
- *Scientific Uncertainty* (SU) is concerned with opportunities provided for students to experience scientific knowledge as arising from theory-dependent inquiry, evolving and non-foundational, and culturally and socially determined. The items in this scale include, "I learn that science is influenced by people's values and opinions."

A Korean-translated version of the CLES was administered to students in March when a new academic year began in Korea. The survey was repeated in the middle and end of the year so that it could yield data across time. Students were asked to respond to each item in the CLES by using five-point Likert scale. The mean scores for each subscale of the CLES were computed to indicate the level of student perceptions of their science classrooms as constructivist. The internal consistency reliability of each CLES subscale was usually greater than .70 when the Chronbach alpha (a) coefficient was used.

Student attitudes were measured by the Enjoyment of Science Lessons Scale (ESLS). ESLS is one of the seven scales of the TOSRA, a well-known instrument for assessing affective views of science among secondary school students (Fraser, 1981). The ESLS includes ten items, which address student feelings about learning science in school. Examples of the items in the ESLS are "Science lessons are fun", "Science is one of the most interesting school subjects," and "The materials covered in science lessons is uninteresting." The ESLS was translated into Korean and administered to students in the same way as the CLES. The Chronbach alpha (a) coefficients for the ESLS were generally greater than .90.

Data analysis

The same data analysis method was applied to both Year 1 and Year 2 projects. Descriptive statistics (i.e., means and standard deviations) were computed for the three temporal sets of the CLES and ESLS data in order to show general patterns of change in student perceptions of and attitudes toward science lessons. The Repeated Measures Analysis of Variance (ANOVA) was then performed to identify the presence of significant change over time. In order to examine the associations of the constructivist elements with changes in student attitudes, the SAS® PROC MIXED procedure was used. In a mixed linear model, student attitudes are considered as a dependent variable while five elements of the constructivist-learning environment were explanatory variables. This method allowed dealing with the repeatedly measured data altogether instead of treating the three temporal data sets separately. The result provided statistical evidence of which element(s) of a constructivist learning environment accounted the most significantly for the change in student attitudes across time, when considered together with other elements in the model.

Results

Table 1 presents the descriptive statistics and the results of the Repeated Measures ANOVA for the data collected at three time periods during the school year. In general, the mean scores for each CLES subscale and the ESLS increased over time. This pattern of change was much the same for the first and second years of the action research projects. According to the Repeated Measures ANOVA test for the Year 1 data, statistically significant changes occurred for the PR, SN, SC, and CV subscales of the CLES as well as for the ESLS. For the Year 2 data, changes with regard to the PR, SN, SC, and ESLS were statistically significant. These results indicate that the science classrooms became more constructivist through the action research efforts and that such development of constructivist science classrooms contributed to changing student attitudes about science lessons in a positive direction.

Table 1
Summary of Statistics for the CLES subscales and the ESLS

Scale	Mean (S.D.)			F†	*p*
	Beginning	Middle	End		
Year 1					
PR	2.66 (.75)	2.80 (.75)	2.96 (.67)	F (1.88, 116.42) = 7.28	.001**
SN	2.28 (.60)	2.96 (.78)	2.97 (.67)	F (1.75, 108.52) = 40.52	.000**
SC	1.92 (.61)	2.29 (.63)	2.48 (.60)	F (1.87, 115.79) = 31.00	.000**
CV	2.14 (.62)	2.49 (.67)	2.44 (.57)	F (2, 124) = 10.03	.000**
SU	2.82 (.57)	2.90 (.52)	2.87 (.54)	F (1.75, 108.46) = .47	.599
Student Attitudes	2.67 (.83)	2.89 (.87)	2.96 (.75)	F (1.86, 113.20) = 6.32	.003**
Year 2					
PR	2.91 (.70)	3.07 (.66)	3.41 (.63)	F (1.80, 106.01) = 17.16	.000**
SN	2.77 (.53)	3.01 (.64)	3.17 (.61)	F (2, 116) = 13.86	.000**
SC	2.22 (.66)	2.49 (.75)	2.63 (.69)	F (1.86, 109.50) = 11.49	.000**
CV	2.34 (.45)	2.44 (.58)	2.53 (.57)	F (1.79, 103.72) = 2.64	.082
SU	2.85 (.50)	2.85 (.50)	2.94 (.50)	F (2, 118) = 1.56	.215
Student Attitudes	3.13 (.80)	3.32 (.76)	3.42 (.60)	F (1.69, 99.94) = 5.25	.010*

†Adjusted degrees of freedom were used when the sphericity assumption was violated.

* $p < .05$, ** $p < .01$

Table 2 illustrates the results from the PROC MIXED procedure and displays significance tests for the overall effects of the explanatory variables listed in the statistical model on the change in student attitudes across three different times during the year. The finding was the same for both Year 1 and Year 2 projects. That is, when all the constructivist classroom elements were taken into consideration in the model, time effect was not significant. As for the five constructivist elements, the effects of SN, SC, CV, and SU were not significant, but the test for the PR effect was statistically significant at the .01 level. This indicates that, out of the five components of a constructivist-learning environment, the PR is the most important factor for accounting for the increase in the degree of positive student attitudes during the school year.

Table 2
Test for the Effects of the Constructivist Classroom Elements on Changes in Student Attitudes toward Science Learning in School

Explanatory Variable	Numerator df	Denominator df	F	*p*
Year 1				
Time	1	117	.86	.356
Time ¥ Time	1	117	.86	.351
PR	1	117	56.25	.000**
SN	1	117	1.78	.184
SC	1	117	1.12	.292
CV	1	117	2.53	.114
SU	1	117	.71	.401
Year 2				
Time	1	109	1.22	.272
Time ¥ Time	1	109	1.81	.181
PR	1	109	65.12	.000**
SN	1	109	2.04	.156
SC	1	109	.37	.543
CV	1	109	.12	.725
SU	1	109	.26	.609

** $p < .01$

Discussion

The results of this study indicate that students' attitudes toward science lessons developed more positively as their science classrooms became more constructivist. This supports the effectiveness of the development of constructivist learning environments on changes in student attitudes in a more positive direction. Specifically, the PR as one of the dimensions of a constructivist-learning environment proves to be the most significant variable to explain the increase in the level of positive student feelings concerning science learning in school. This finding is congruent with previous studies, which showed that the PR was one of the important factors influencing student attitudes about science and science learning (Aldridge et al., 2000; Fisher & Kim, 1999).

Relevancy is concerned with the connectedness of science learning to student out-of-school lives. To strengthen the PR aspect, science lessons should make use of student everyday experiences as a context for learning science. Problem-Based Learning (PBL) and Project-Based Science (PBS), among other instructional models, are approaches, which contribute to making science learning more relevant to students. PBL places students in inquiry-oriented learning situations in which they work individually and collectively in order to solve real or realistic problems (Duffy & Cunningham, 1996; Savery & Duffy, 1996). PBS involves student investigations on research topics, which can be explored from multiple disciplinary perspectives including science (Blumenfeld et al., 1991; Marx et al., 1997). While the differences between PBL and PBS are subtle (Esch, 1998), these two models are based on developing instructions around problems or topics on which students are to work. A problem or topic can be determined in two ways. The teacher may present problems or topics in such ways that students will readily take them as their own. For example, in a medical school, students in groups are presented problems in the form of patients with symptoms. The tasks of each student group include to diagnose the patients, to provide rationales for the diagnoses, and to recommend some treatments. (Duffy & Cunningham, 1996; Savery & Duffy, 1996). Alternatively, the teacher can solicit problems or topics from learners. In Science, Technology, and Society (STS) approaches to science instruction, students bring some questions and issues from their everyday lives to the classroom and learning is designed and developed around these questions and issues (Yager, 1995; Yager & Lutz, 1995). Authors agree that problem-solving and project activities are more meaningful when students are allowed to proceed with problems and topics of their own choosing (Marx et al., 1997; Wolk, 1994).

PBL and PBS have been used mostly in elementary or postsecondary classrooms. However, these approaches are appropriate for secondary school science as well because inquiry into problems and topics relevant to students is an essential component of science education across all grade levels. Implementation of PBL and PBS in science classrooms is also timely since inquiry learning in the classroom community is a key principle of today's science education reform efforts (AAAS, 1990; NRC, 1996). In these circumstances, PBL and PBS are advantageous in that these approaches provide inquiry-based, cooperative learning environments while also strengthening the relevancy of science learning to students. The GI method, which was employed as a general instructional approach for the action research classes addressed in this study, is believed to provide a protocol for how PBL and PBS may proceed in the science classroom.

Although this study found that the relevancy of a science class to students was associated most strongly with positive changes in student attitudes toward science learning, this result does not mean that other elements of a constructivist science classroom are not concerned with how students feel about learning science in school. Further research is needed to explore how such constructivist elements as SN, SC, and CV affect student attitudes and learning practices in the classroom. Moreover, the effects of constructivist science learning on other science learning outcomes should be examined in ways that can provide practical implications for science education reforms.

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