Jour. Korean Earth Science Society, v. 27, no. 3, p. 269–278, June 2006

A Study on Pre-Service Teachers' Perception of Learning Environment in Earth Science with Using Virtual Reality (VR): An Exploratory Case

Myeong-Kyeong Shin[1,*], Hee-Soo Kim[2], and Jong-Heon Kim[2]

[1]Science Education, Gyeongin National University of Education, Incheon 407-753, Korea
[2]Earth Science Education, Kongju National University, Chungnam 314-701, Korea

지구과학에서의 가상 현실의 사용에 따른 예비 과학교사의 학습환경 인식 연구: 시험적 적용

신명경[1,*] · 김희수[2] · 김종헌[2]

[1]경인교육대학교 과학교육과, 407-753 인천 계양구 계산동
[2]공주대학교 지구과학교육과, 314-701 충남 공주시 신관동

Abstract: In this study, we used Virtual Reality (VR) materials on an introductory earth science course consisted of thirty six pre-service science teacher program students. Before and after class an instrument of Constructivist Learning Environment Survey (CLES) was administered. The main focus of the CLES was to evaluate how the classroom was prepared for student centered learning environment. The pre and post tests of student perceptions regarding their learning environment were compared in six domains: personal relevance, critical voice, shared control, student negotiation, scientific uncertainty, and attitude. Questionnaire regarding the general perception of the VR materials was administered as well. How future science teachers valued the use of VR materials in their classrooms was found from this study. Based on these results, we intend to contribute for a more complete understanding of the potential of VR materials in achieving better learner-centered classroom environment.

Keywords: constructivist learning environment, virtual reality, changes of perception

요 약: 본 연구에서는 교양지구과학과목을 수강하는 36명의 예비과학교사를 대상으로 가상현실(VR)의 사용을 한 차시에 걸쳐 시도하였다. 수업을 하기 전과 후에 구성주의 학습환경 조사(CLES)를 실시하였다. CLES의 주된 초점은 수업이 학생중심 수업환경을 얼마나 잘 보조하고 지원하는가다. 학생의 자신의 수업환경에 대한 사전 및 사후검사는 여섯 가지 하위 영역으로 나뉜다.: 학생적절성, 비판적 시각, 교실통제의 나눔, 학생 간의 타협, 과학적 불확정성, 태도이다. 아울러 가상현실에 대한 미래교사의 인식에 대한 설문지도 실시하였다. 미래의 과학교사들이 가상현실 자료를 교실에서 사용하는 것에 대하여 어떻게 생각하는가를 본 연구를 통해 알아보고자 했다. 이들 결과를 바탕으로 교사 주도의 수업 환경을 학생의 적극적 참여를 유도하는 수업에로의 변화를 도모하는 것과 같은 기존에 연구되지 않은 측면을 제안하여 가상현실의 잠재력에 대한 보다 완벽한 이해를 꾀하려 하였다.

주요어: 구성주의 학습환경, 가상 현실, 인식 변화

*Corresponding author: mkshin@ginue.ac.kr
Tel: 82-32-540-1248
Fax: 82-32-540-1239

Theoretical Backgrounds

Earth Science Educational Needs: Better Learning Occurs Not inside of Laboratories

It is in the field that a student makes contact with the evidences that forms the basis of the earth sciences (McDonnell, 1973). Fields experience provides something that no amount of description or illustration can give. No teacher of earth science would question the value of such experiences. Yet neither would anyone who has tried to provide a full and varied program of field studies in a school deny the difficulty of such an undertaking (McDonnell, 1973). The traditional use of laboratories at earth science courses does not reveal their learning potential. Even it is true for field trips at the end of a geology course (Orion, 1989).

Further there are so many concepts dealt in earth science related courses to be possessed by students' imagination such as solar system or extra-galaxy rather than by experimentation and observation of concrete evidences. In reality, it does not happen to take students out of school building during the semester. Earth science classes will not be an exception. What if we can have rebuild the very live field situation inside school? Technology enables exciting virtual field-trips excursions students can take while remaining in the comfort of classroom (Goldsworthy, 1997). While simulated excursions using multi-media like virtual reality, they do in fact offer an interesting and challenging way to learn. VR excursions or simulation can be thought of as substitutes for the effective learning of earth science.

School science courses to deal with oceanography, meteorology and astronomy need to use the real and current data and images by way of National Oceanic and Atmospheric Administration (NOAA), the National Aeronautics and Space Administration (NASA), the U.S. Geological Survey (USGS), Korea Astronomy and Space Science Institute (KASSI), Korea Meteorological Administration (KMA) and so on. With the introduction of the technology and powerful classroom computers paired with high-resolution screen, the problem of accessing data will be changed to one of managing data. Students will learn firsthand how remotely sensed images are built in virtual reality, and their science class will be enhanced (Sproull, 1991).

Student-Centered Classes

As in the case with any educational theory, the primary consideration of educators is how that theory translates into meaningful student learning. An examination of the tenets of student centeredness suggests that many schools are not presently operating in accordance with the axioms of this theory of knowledge construction (Yager, 1991). Traditional science classes typically involve student learning that consists of memorizing key definitions and provides direction for getting answers to problems given. Many times answers to such problems are generally known ahead of time: students often manipulate problems to get right answers without knowing what they are doing and why they are doing it (Anderson et al., 1994).

Much of what drives student centered teaching practices can be attributed to the misguided educational system's reliance on standardized achievement tests by many teachers, administrators, parents, and community leaders. Gardner (1991) identifies the discrepancy between perceived and actual success as the difference between learning and performance. When the emphasis is placed on performance (e.g., getting high scores), what usually results in is short-term recall of factual information while an emphasis on understanding results in meaningful learning.

This student centered view is based on constructivism. Such view of learning posits that individuals construct new knowledge as they are engaged in experiences that provide them with new information. For a student, many times this new information must be reconciled with what he/she already knows or believes about a particular phenomenon or event. When this information conflicts with a student's prior conceptions, he/she is confronted with a discrepancy that must be resolved.

This discrepancy is generally resolved as the student begins to take into account additional variables new information resulting in a more sophisticated understanding than he/she previously held (Brooks and Brooks, 1993).

There has been a long history of research on learning in science classrooms (Anderson and Mitchener, 1994). Until recently, the focus has been on student learning as evidenced from standardized instruments often administered by external agencies. The focus now has shifted to studying the ideas and beliefs that pupils bring into the learning process taking into account constructivist theory (Confrey, 1990; Driver and Bell, 1986; Osborne and Wittrock, 1985; Von Glasersfeld, 1989). Recent research in science education indicates that an understanding of the knowledge of scientific phenomena that pupils bring to class is critical for successful teaching and learning (Driver et al., 1985).

Research has shown that first-hand, direct sensory experiences for students provide necessary opportunities for them to develop their current knowledge. They can experience the cognitive conflicts which in turn can lead to new knowledge construction (Saunders, 1992). In this context, virtual reality can help student centered class come true. While it is the beginning stage of research in virtual reality material usage for school science, discussing on what else we can expect from use of virtual reality in classes is worthwhile. In this study, we proposed that virtual reality would allow students to organize and control their own learning. In other words, students could share their control with teachers.

Using Virtual Reality: Pro and Cons

We tried to see if preservice teachers who experienced the clip of VR materials in earth science course view that VR could assist teachers to move toward sharing control of class with students. However still there are debating between pros and cons on using virtual reality in classes. Some of them is followed.

Firstly, VR is to provide experiential learning environment. We experience the environment as if it were real, while still fully aware that it is computer-generated. Educational theorists have agreed on the fundamental importance of experiential learning for over a hundred years: Knowledge begins with enaction (Bruner, 1962). Also affective domain of learning outcome has been carefully explored (Kohlberg, 1968). VR is experiential computing environment to provide a context for both cognitive and affective learning by engaging students in a process that is rational and emotional, practical, organized and spontaneous.

Secondly VR learning environment is a shared experience. Virtual worlds can be both individual and social contexts. Networked VR allows multiple participants to interact simultaneously in the same audio-visual environment, sharing control naturally while conversing with augmented capability. Similarly, VR learning environments can be tailored to individuals as well.

In addition, student achievement and attitude can be improved because of the visualization offered by making instructions more 'real world'. VR environment provides the opportunity to work in more concrete and stimulus-rich environment. It allows for instruction to be anchored in a meaningful context. Therefore, the achievement of students is highly expected through VR environment in science class (Wisnudel, 1994; Jones, 1994; Jiang and Potter, 1994; Nakhleh, 1994; Trumper, 2001). Also students will display a more positive attitude towards learning in VR environment due to the novelty of the media and its visual appeal (Adams, 1996). Students may be challenged to create an original artifact and not merely be passive receivers of information or reproduce knowledge from a text book (Blumenfeld et al., 1991). That is, allowing students to decide how to plan and work on their artifacts may engage them in the learning process (Wisnudel, 1994).

There are also several reported concerns regarding usage of VR materials. They are high cost in developing hardware and software. The production of science curricula VR materials is difficult and expensive. Secondly a crucial issue for integrating VR into classrooms is a system usability by students of various ages, by teachers, and by curriculum developers. The third one is fears of educators. They are concerned that more technology that they are not trained to use will be dropped into the classroom, and that it won't really help them to teach more effectively. Lastly, VR materials are much talked about in connection with reforming the existing systems. Unfortunately there are no evaluation schema to determine the quality of such materials in forms of current reforms of science education.

These pros and cons on VR material uses in earth science education motivated the current research. Followed are the research questions guiding this study:

- Does using Virtual Reality in an earth science course affect preservice teachers' perception on learning environment?
- How do preservice teachers view the usage of Virtual Reality in learning?
- Are there any differences in perception on learning environment and general perception on using Virtual Reality in classes according to preservice teachers' gender and their subject major areas of physics, biology and chemistry?

Research Context

There have been efforts on shifting from teacher-directed toward student-centered classrooms as determined by students' perception of their learning environments (Shin et al., 2003). One of the instruments for student perceptions of their learning environment in the viewpoint of student-centered classes is the Constructivist Learning Environment Survey (CLES) (Yager, 1998). However previous literatures and documentations reported huge difficulties and impediments of stepping away from teacher-centeredness (Yager, 1998; Shin et al., 2003; Oh, 2003). This situation was pertaining to not only K-12 students but also students in teacher education programs. It was learned from science educational research that teachers teach as they were taught in schools. It is consequently followed that more cares may well be taken of future science teachers.

In a mean while, a suggestion for avoiding impediments for moving toward student-centered classes was to adopt virtual reality learning environment. It was rooted from the idea of that VR offers teachers and students unique experiences that are consistent with successful instructional strategies: hands-on learning, group projects and discussions, field trips, simulations, and concept visualization. Within the limits of system functionality, we can create anything imaginable and then become part of it. The VR learning environment is experiential and intuitive; it is a shared information context that offers unique interactivity and can be configured for individual learning and performance styles.

In this study, we used VR materials in teaching 36 pre-service teachers with an introductory earth science class. Before and after the VR class, the CLES was administered to find the effects of VR materials on their perception of learning environment. Figure 1 showed a clip of the VR teaching material. The pre- and the post- tests of students perceptions regarding their constructivist learning environment were compared in six domains; personal relevance, critical voice, scientific uncertainty, shared control, student negotiation and attitude. Further as future science teachers, we asked them of general

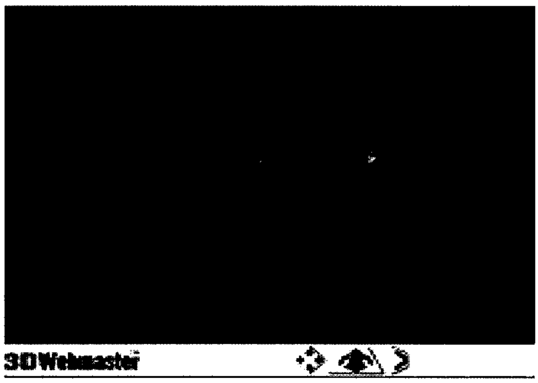
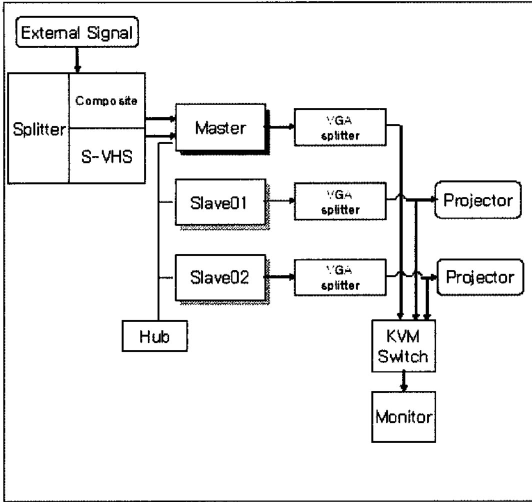


Fig. 1. A clip of the VR materials of solar system used.



NOVA Infinity software (Based OpenGL 1.2)
Provide a full Compatibility with VRML97
Microsoft Window 2000 Professional
1 Master, 2 Slave computer system (VisionMax)
Intel P4 2.53GHz
Geforce4 Ti4600 V8486
3D Sound & Distinguish direction and distance
350 inch Silver screen
4 projectors (for 2(Right, Left) 2(wide screen))
Overlapped Channel Display for Soft Edge Blending
Spacecraft Interior
Vibrating floor
Dolby surround system

Fig. 2. System structure and specifications (Lee et al., 2005).

questions with regard to VR materials and science education as well as their expectation of VR science class.

Based on the pre-service science teachers perception differences after an exposure of VR science class, several implications were made pertaining to future prospect of VR in science teaching occurred in K-12 as well as in pre-service program.

System Features

The virtual solar system reviewed in our study is an VR based on high-resolution spacecraft images of the solar system, including the sun and the planetary objects. It was developed as part of a comprehensive astronomy education program aimed at secondary school students or undergraduate students. The objects revolve in their orbits against the constant background of the Milky Way and the stars. The solar system was scaled down and calibrated with great accuracy. A student can use the pointing device to change his/her viewpoint while 'flying' in 3D astronomical space. The virtual solar system has a dynamic frame of reference, which can be altered by choosing different objects as an origin. Our main goals were to describe and analyze the conceptual development of secondary school students' understanding of the basic astronomical phenomena during real-time interaction with a virtual solar system. Fig. 2 is our VR system structure and specifications (Lee et al., 2005). But this system did not provided immersive environmnent with any of floor vibration, space-ship setting, audio effects and so on.

Research Methods

The context of this study is a college earth science course, which is introductory level. Thirty six of pre-service teachers attended in the VR class. They were never been exposed with immersive virtual reality in learning science except playing with VR games. Before the VR class, data of students' perceptions on their learning environment mainly in direct teaching or teacher centered lecture were collected, which is defined as 'previous science teaching' in fig 3. In the following period of the VR class, the same questions were asked regarding perceptions on their learning environment of using VR materials. In summary, a treatment of this study is a VR class. We tried to see how students perceive their learning environment differently before and after using VR in class. Figure 3 showed the scheme of this research.

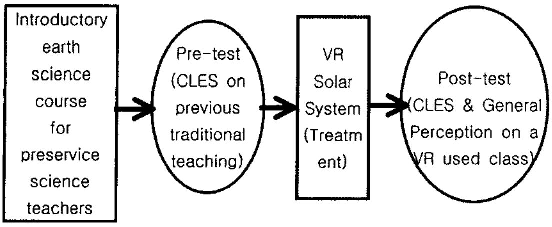


Fig. 3. Research scheme.

Subjects

Total of 36 pre-service science teachers were involved in this study. Most of students are in age range of 21 and 25 years: we divided into three groups of 21-22yrs, 23-24yrs, and over 24yrs. The numbers of male and female students is 15 and 21. Their majors are chemistry, biology, and physics in the order of number of students :the numbers are respectively 16 (Chemistry), 11 (Biology) and 9 (Physics).

Instrumentation and Data Analysis

Two instruments were used for this study. The CLES, adapted from Constructivist Learning Environment Survey were used to investigate the changes in student perceptions regarding their classroom learning environment. The CLES instrument consists of 42 statements about the classroom learning environment. Students were asked to rate how each statement applied to themselves and their class on a Likert scale which included the following choices: Almost never (1 point), seldom (2 points), sometimes (3 points), often (4 points), and almost always (5 points).

The CLES instrument includes six sub-scales including the followings:

The personal relevance (PR) scale concerned with student's experience of thepersonal relevance of school science as perceived by students. The scale has been designed to measure the extent to which students perceive the relevance of the context included in science course to their out of school lives. The scientific uncertainty (SU) scale is concerned with perceptions of science as a fallible human activity as perceived by students.; The critical voice (CV) is concernedwith student development as autonomous learners. The scale assesses the extent to which students are able legitimately to question the teacher's pedagogical plans and methods and to express concerns about any pediments to their learning. The shared control (SC) is concerned with students sharing control of the learning environment with the teacher. In particular, the scale assesses student perceptions of the extent to which the teacher involves them in the management of the constructivist learning environment, including articulating their own learning goals, designing and managing their own learning activities, and determining and applying assessment criteria. The student negotiation (SN) is regarding negotiation amongst students. And the attitude (AT) is concerning student attitude toward science class and scientific enterprise.

The another instrument is a simple questionnaire regarding a general perception about VR materials. For this study, we created the 14 questions. These fourteen questions were categorized into four groups. The first one is familiarity with VR, which mostly asked how much students know about VR.; the second is VR in science education, whose questions were regarding how VR will affect science teaching and learning; the third is future prospect of use of VR in education.; the last is whether students are willing to engage themselves in learning VR and using VR in classroom. As far as validity of this instrument concerned, the question items were proposed and examined by three science educatotrs who are Ph.Ds in science education. This perception instrument used also Likert scale with five choices. List of the questions are followed:

part 1: Familiarity

I know very well about Virtual Reality (VR).

I have experienced and used VR.

part 2: Connection with Science Education

I believe VR help teaching and learning.

I believe science education is the field to be benefitted by VR.

VR can help students understand abstract scientific concepts.

VR will not be helpful for students' understanding of scientific concepts.

Using VR will help students motivation of science learning.

part 3: Future Usage

Engineering and medicine will use VR very effectively.

In the future, VR will be more frequently used.

Because of its high expense, VR will not be used in school.

In actual classes, materials related to VR will not be used much.

VR contents development will be the most difficult problem.

part 4: Personal Involvement

I will use VR in science teaching.

I am willing to participate at working for VR.

The Cronbach's alpha reliablility coefficients for each of the six sub-scales of CLES were reported to range from 0.54 to 0.85 in previous research. Repeated measures T-tests was utilized for the analysis of CLES scores.

Results and Discussion

Perception on Use of Virtual Reality

Students' responses to a questionnaire of general perceptions of VR were discussed with four categories. The mean scores for the four categories are shown in Table 1.

In the questionnaire, 1 and 2 points means negative student perceptions and 4 and 5 points positive. Point 3 means 'undecided'. Based on this rating system, the pre-service teachers in this study perceived VR to be a little familiarity. The similar mean score was found in the category of future use of VR in education. The students viewed VR materials to be useful for understanding scientific concepts and teaching science. Also more than 60% of students responded that they would participate in any workshop or program to learn VR in the future.

Differences in student perceptions regarding their science classrooms using VR

The pretest and posttest were administered before and after the VR material class. Table 2 represents means and standard deviations for the six different sub-scales from CLES. The mean gap score (pretest posttest) for the six sub-scales is represented in Table 2. The patterns of changes in student perceptions regarding their classes showed that there were observed improvements between pretest and posttest. Table 2 also presents the results of the repeated measures T-test. The results of T-test indicated that the overall changes in student perceptions were statistically significant ($p < 0.05$). It means that student perceptions regarding their science classrooms were significantly improved after using the VR class compared to traditional lectures. However, among sub-categories, AT (attitude) and SC (shared control) were only categoies to show significant differences.

The results regarding student perceptions of personal relevance (PR) reveal that students perceive that the VR class makes as much use of student's everyday experiences as meaningful contexts for the development of students' scientific knowledge as their traditional lectures statistically. There are no significant differences in the perceptions of incorporating scientific uncertainty (SU) between the VR class and classes with traditional methods. Similar results were found in a critical voice (CV). There are no significant differences after the VR class in CV. It was repeated in a student negotiation (SN).

Table 1. Student perceptions on use of VR in general (N = 36)

	Future use of VR	VR in science education	Familiarity with VR	Engage yourself in learning VR
Mean	3.4537	4.2000	3.4167	3.9167
SD	.4339	.4611	.6918	.8409
Variance	.1883	.2126	.4786	.7071

Table 2. Differences of pre and posttest scores of each sub-category of CLES (N = 36)

		Mean	Paired Differences		t	Sig. (2-tailed)
			Mean Difference	Std. Deviation		
Personal Relevance (PR)	Pretest	3.2167	-.1500	.1390	-1.08	.288
	Posttest	3.3667				
Scientific Uncertainty (SU)	Pretest	3.2056	-.2833	.1502	-1.89	.068
	Ppsttest	3.4889				
Critical Voice (CV)	Pretest	2.9583	-.2546	.1658	-1.54	.134
	Posttest	3.2130				
Student Negotiation (SN)	Pretest	2.9603	-.3016	.1567	-1.92	.063
	Posttest	3.2619				
Attitude (AT)	Pretest	3.0069	-.4306	.1797	-2.40	.022*
	Posttest	3.4375				
Shared Control (SC)	Pretest	2.2540	-.7619	.1698	-4.48	.000*
	Posttest	3.0159				
Total of CLES	Pretest	2.9336	-.3637	.1310	-2.78	.009*
	Posttest	3.2973				

*Significance at alpha = 0.05.

The results with regard to student perceptions of having shared control (SC) and student attitude toward science class (AT) scale resulted in statistically significant difference between pre and posttest. It means that students with VR material approaches perceive the class to provide students more shared control and had more positive attitude towards science classes compared to those taught with traditional methods. Similar results were found when the new method of teaching or new strategies were tested in science classes in previous research (Oh, 2003; Shin et al., 2003).

Using VR in science teaching: facilitating learner-centered classroom environment

The results regarding the shared control sub-scale indicate that students with the VR class perceive that their class involve students more in planning, conducting lessons, and assessing their own learning compared to those in traditional classrooms. However, the shared control sub-scale scored the lowest among the six-sub scales of CLES instrument in both the traditional lectures (pretest) and the VR class (posttest) despite of significant improvements in the posttest (Table 2).

The results clearly imply that planning, conducting lessons, and assessing student learning are mostly carried out by teachers without student involvement. This study implicates that appropriate usage of VR materials in science classes is one of the solutions of avoiding such impediments in accomplishing learner-centered science classes for better student learning. Of course, it must be presumed scenario of usage of VR rather than a proven one.

Gender and Major Differences

While there was no statistically significant differences between male and female students, we could see clearly certain tendency. More female students viewed than male students that VR materials used class worked on better student-centered learning environment especially in a sub-category of shared control ($p = 0.03$). Among other sub-categories, it is only one to be statistically significant In other researches using CLES instrument (Yager, 1998; Oh, 2003), the critical sub-category always turned out to be 'shared control'. It is worthwhile to note that using VR materials in class seemed to bring about similar results in learning environment perception of students.

In other hand, there were no significant differences in any sub-category for comparing subject majors. However, overall tendency indicated that more physics education major students possessed steadily lower expectation on VR materials than either biology ed. students and chemistry ed. students. Yet, it was not supported by statistical analysis. It was the similar case in the previous survey results on students' general perception on VR materials in learning where scores of physics education major students were generally higher than any other students.

Concluding Remarks

This study had three research questions. One was to examine the effectiveness of the VR material-used class for pre-service teachers in terms of their perceptions regarding their science learning environments. The second was to investigate students' perceived effectiveness and prospects of using VR materials in teaching and learning science. The last one was to compare the perceptions according to genders and subject major groups. The overall finding of these questions was that students perceived the use of VR in science classrooms to be prospective and positive regardless of their genders and subject majors.; except the result of that more female than male preservice teachers viewed their VR class significantly more student-centered in terms of 'shard control' sub-category. Of course in the previous research, effects and impediments of using VR in science teaching and learning were discussed (Gordin and Pea, 1995; Kim, 2002; Shim et al., 2001). This study explored the aspect of learning environment perceived by students as future science teachers.

Also, the findings provided evidence that VR class is effective in moving science classes toward learner centered class. These result provided insights for studies concerning proven teaching methods using VR materials for improving student learning as well as classroom environment. Based on comparative analysis of CLES before and after using VR in an earth science course with preservice teachers, we learned that VR materials could cause a similar effect on learning environment with utilizing new teaching strategies and methods. When it is popularly accepted that technology does not affect on substantial learning outcome including perception of learning, this interpretation might be encouraging for VR developers for the use in science classes.

Yet a conclusion and generalization of moving toward student-centered or remain as teacher-directed as a result of using VR materials in science teaching may well be postponed and left to following researchers who will collect more abundant evidences to support them. As the survey result indicated, pre-service teacher education programs should prepare their students for using VR materials in their course works in order to meet their needs of being professional science teachers in near their future.

Limits of the Study

There were some limits for further discussion of this research. First we needed more in-depth understanding of students perceptions on VR by student interviews. Secondly we needed to know more about how VR affects on student understanding of astronomical concept. In the future research work, these are recommended most.

References

Adams, P.E., 1996, Hypermedia in the classroom using earth and space science CD-ROMs. Journal of Computers in Mathematics and Science Teaching, 15 (1-2), 19-34.

Anderson, R.D., Anderson, B.L, Varanka-martin, M.A., Romagnano, L., Bielenberg, J., Mieras, M.B., and Whitworth, J., 1994, Issues of curriculum reform in science, mathematics, and higher order thinking across the disciplines. The Curriculum Reform Project, U.S. department of education grant No. RR91182001, 144 p.

Anderson, R.D. and Mitchener, C.P., 1994, Research on science teacher education. British Journal of Sociology of Education, 6 (3), 307-332.

Blumenfeld, P.C., Soloway, E.I., Marx, R.W., Krajcik, J.S., Guzdial, M., and Palinscar, A., 1991, Motivating project-based earning: Sustaining the doing, supporting the learning. Educational Psychologist, 26 (3-4), 369-398.

Brooks, J.G. and Brooks, M.G., 1993, In Search of understanding: the case for constructivist classrooms. Association for Supervision and Curriculum Development, Alexandria, 145 p.

Bruner, J., 1962, On knowing: essays for the left hand. Cambridge, MA, 165 p.

Confrey, J., 1990, What constructivism implies for teaching. Journal for Research in Mathematics Education, Monograph No. 4, 107-222.

Driver, R. and Bell, B., 1986, Students' thinking and the learning of science: A constructivist view. School Science Review, 67, 443-456.

Driver, R., Guesne, E. and Tiberghien, A., 1985, Children's ideas in science. Open University Press, PA, 108 p.

Gardner, C.M., 1991, The unschooled mind: how children think and how schools should teach. Basic Books, New York, 320 p.

Goldsworthy, R., 1997, Real-world field trips. Learning and Leading with Technology, 24 (7), 26-28.

Gordin, D.N. and Pea, R.D., 1995, Prospects for scientific visualization as an educational technology. The Journal of the Learning Sciences, 4 (3), 249-279.

Jiang, Z. and Potter, W.D., 1994, A computer microworld to introduce students to probablity. Journal of Computers in Mathematics and Science Teaching, 13 (2), 197-222.

Jones, T., 1994, Video and multimedia for math and science instruction. Journal of Computers in Mathematics and Science Teaching, 13 (2), 128-145.

Kim, H.S., 2002, The use of virtual reality in web-based earth science education. Journal of Korean Earth Science Society, 23 (7), 531-542.

Kohlberg, L., 1968, Early education: a cognitive-development view. Child Development, 39, 1013-1062.

Lee, H., Park, S.T., Kim, H.S., and Lee, H, 2005, Students' understanding of astronomical concepts enhanced by an immersive virtual reality systems (IVRS). Recent Research Developments in Learning Technologies, 3, 1118-1122.

McDonnell, K.S., 1973, Multi-Media field studies- a development in earth science teaching. The Australian Science Teachers Journal, 19 (1), 53-56.

Nakhleh, M.B., 1994, A review of microcomputer-based labs: how have they affected science learning?. Journal of Computers in Mathematics and Science Teaching, 13 (4), 368-403.

Oh, P.-S., 2003, Changes in science classrooms resulting from collaborative actional research initiatives. Ph.D. Dissertation, University of Iowa, Iowa, 197 p.

Osborne, J.F. and Wittrock, M., 1985, The generative model and its implications for science education. Studies in Science Education, 12, 59-87.

Orion, N., 1989, Development of a high-school geology course based on field trips. Journal of Geological Education, 37 (13), 13-17.

Saunders, W.L., 1992, The constructivist perspective: implications and teaching strategies for science. School Science and Mathematics, 92 (3), 136-141.

Shim, K.C., Park, J.S., Kim, H.S., Kim, J.H., Park, Y.C., and Ryu, H.I., 2001, Exploring application ways of virtual reality technology in science education. Journal of Korean Science Education, 21 (4), 725-737.

Shin, M.-K., Yager, R.E., Oh, P.-S., and Lee, M.-K., 2003, Changes in science classrooms after experiencing an international professional staff development program. International Journal of Science and Math education, 1 (4), 505-522.

Sproull, J., 1991, Understanding #3: Advanced technologies for the study of Earth Systems. Science Activities, 28 (1), 19-22.

Trumper, R., 2001, A cross-college age study of science nonscience students' conceptions of basic astronomy concepts in preservice training for high-school teachers. Journal of Science Education and Technology, 10 (2), 189-195

Von Glasersfeld, E., 1989, Cognition, construction of knowledge, and teaching. Syntheses, 80, 121-140.

Wisnudel, M., 1994, Constructing hypermedia artifacts in math and science classroom. Journal of Computers in Mathematics and Science Teaching, 13 (1), 5-15.

Yager, R.E., 1991, The constructivist learning model: towards real reform in science education. The Science Teacher, 59 (9), 53-57.

Yager, R.E., 1998, Collaboration in science education research 1998. Research proposal package, the University of Iowa, Iowa, 110 p.

2005년 9월 15일 접수
2006년 5월 26일 수정원고 접수
2006년 5월 26일 원고 채택