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Middle School Students' Characteristics of Spatial Ability in Earth Science Activity using Orienteering

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Abstract: The purpose of this study is to analyze students' learning characteristics regarding spatial ability, orienteering ability and earth science content learning ability and their relationship through development and application of earth science activities using orienteering. The programme aims to improve students' spatial ability using orienteering activity which requires spatial ability. Topics in the programme included map, compass, contour, movement of celestial, and constellation application. Students were to orienteer in the field using the method they learned in class. This programme was applied to five 7th graders. The results are, first, students who have positive attitude toward science and do well at school tended to perceive their orienteering ability high. Second, all parts of spatial ability, spatial visualization, spatial orientation, spatial relation were used during orienteering, especially spatial visualization and spatial orientation. The relationship between spatial ability, orienteering ability, and earth science content learning abilities was not clear. However, orienteering ability and earth science content learning ability were in similar tendency.

Keywords: orienteering, spatial ability, earth science learning ability, orienteering ability

Introduction

Earth science is basically spatial science that requires cognitive and mental manipulation of spatial data (Liben and Titus, 2012). Because the nature of earth science, where the spectrum of time and space are large, makes students find it difficult to understand the concept just by observing directly, so school teachers use various pictures and models to help students understand(Lee and Kwon, 2010). Students' spatial abilities are required to transform the 2D data into 3D data. Spatial ability is the one to symbolize or memorize the internal representation in space and relate it to other objects or spatial locations (McGee, 1979). McGee classified spatial ability into spatial visualization and spatial orientation. Spatial visualization is the ability to manipulate, twist and transform visual stimuli by thinking. Spatial orientation is the ability to imagine how visual stimuli or imagine the shapes and looks from other perspectives. Later, Lobben (2007) divided spatial ability into the ability of spatial relationship, as well as spatial visualization and spatial orientation as summarized by McGee. The spatial relationship is the ability to rotate an object by its central axis.

Spatial ability is an important keyword in science education. Despite its importance, it has been overlooked in science classrooms (Mathewson, 1999). "Learning to think spatially" (NRC, 2006) criticized the fact that the K-12 curriculum did not systematically and officially include spatial thinking despite that it was the basis for thinking and solving problems. In Korea, spatial analysis is included in geography in the revised national social studies curriculum of 2015.

It is difficult to understand the actual geological process that takes place over a long period of time and giant size of space with the traditional teaching method which only uses samples, models, and pictures. In this types of class, students can hardly take the leading role in using spatial ability and many studies show students may exhibit conceptual difficulties in interpretation of two-dimensional data, such as topographic maps, aerial photos, and geologic cross

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sections (Ford, 2003; Kusnick, 2002; Wampler, 1999) into three-dimensional reality. This is the reason outdoor class is important for students to experience such as observing, collecting data, interpreting data, building hypotheses, and reasoning. Also, field trips encourage higher levels of participation and hence are followed by deeper levels of learning (Laevers, 2000). According to Folkomer (1981), outdoor learning enhances students' scientific inquiry skills through observation, data collection & analysis, and enforces their understanding of science by linking them to school science concepts. In addition to the cognitive aspect, out-of-school science experience provides students various aspects of science that cannot be learned in the classroom, through effectively improving positive attitudes toward science (Martin et al., 2005).

‘Orienteering’ is a game that uses a map and a compass to locate a few points on the map as quickly as possible (Kim and Choi, 1995). Participants can use maps and compasses to find out the way to get to the destination fastest and the most accurately. Map is one of several tools for expressing spatial data and is an efficient form to logically transfer spatial information (Hemmer et al., 2013). Map-reading is a meaningful activity for helping students understand the direction and improve their spatial ability (Kastens and Liben, 2010). Reading a map and comparing it to the real space needs students’ cognitive strategies. In this process, spatial ability is involved to reduce the gap between map and reality (Kastens and Liben, 2010). Participants should collect and analyze information on maps as well as surrounding environment, which is the basic for logical infer. In other words, orienteering can be a process of collecting information about the surroundings encountered in the process of finding the route, and constructing the spatial cognition by the immediate resolution (Shin and Lee, 2012). There are also several findings that show a significant correlation between orienteering and spatial ability using maps (Beatty and Dunca, 1990; Fenner et al., 2000; Hemmer et al., 2013).

The earth science curriculum consists of contents that can be effectively understood when equipped with spatial capability, such as the movement of the celestial body, the internal structure of the earth, geological structure, and plate movement (Kali and Orion, 1996). Students feel difficulty in interpreting 3D distribution of geologic structures and strata in the sub-surface using 2D data, such as the relationship between geological boundary and contour lines in geological map (Lee and Kim, 2004). Lee (2008) showed that Korean 5th grade students who have higher level of spatial ability understood the earth science knowledge at deeper level. In other words, enhancing spatial ability can be an important factor for developing science inquiry ability (Kim et al., 2005). Tracy (1990) also found that students with higher spatial ability had higher scientific achievement than those with lower spatial ability. As these studies support, spatial skills are essential for students to understand the specific concepts involved in earth science subjects.

Previous studies have shown that spatial ability in earth science is essential, but there are not many studies showing how to actually improve students’ spatial ability in earth science classes. This means more studies and educational program developments are needed to relate earth science education to spatial ability. In this study, the purpose is to develop and apply an orienteering programme, which requires spatial ability, for middle school students in earth science context. The research problems to be studied in this study are as follows.

1. To evaluate students’ self-perception of their orienteering ability by their characteristics.
2. To categorize characteristics of orienteering and the spatial ability that are used in the process.
3. To analyze the relationship between spatial ability, orienteering ability, and earth science content learning ability.

Methods

In this study, we developed an educational programme that utilize earth science contents and to use spatial abilities and applied it to students. Tests were conducted before and after the programme to measure the students' abilities. The programme was applied and the activities of the students, the interviews after the programme, and the activity sheets students produced every class were recorded and analyzed. The quantitative analysis of the students' tests results was used to deeply investigate what the qualitative analysis of the characteristics of students' activities and subsequent interviews revealed.

To develop an orienteering programme to enhance spatial skills in earth science, we first analyzed previous researches on spatial capacity in earth science. In this process, we elaborated research theme by developing and applying 'orienteering', which requires comprehensive research ability to utilize spatial ability in various fields. Because there are many educational advantages of outdoor activity, we developed outdoor orienteering programme. Based on various books and research papers related to orienteering, we selected research participants after organizing educational goals, learning contents, and orientation activities of each class. Before applying the orienteering programme, students were asked about their previous orienteering experiences, their perception about their orienteering ability and orientation ability. At the same time, they conducted a test of their spatial ability. After that, six classes were taught. After the class, students were tested for orienteering ability and spatial ability by using the same test as the previous one. Based on the collected data, semi-structured interviews were individually conducted. All of the students' course and activities were recorded, students' written tests and activities were collected, and all interviews were recorded and analyzed.

To develop the orienteering programme, we analyzed current curriculum and prior research on spatial ability and orienteering. Spatial competence is included in various grades and subjects from grade 3-4 to grade 10. In social studies, basic elements of map, use of spatial data and tools, map reading, geographical information, geographic information technology are taught throughout third grade to ninth grade in area of geographical awareness. Mathematics deals with stereographic shapes in geometric domain. While spatial ability is explicitly addressed in social science and mathematics. In the other hand, even though many chapters in science need spatial ability, there were no unit that were explicitly constructed to enhance spatial ability.

The contents that were explicitly addressed about orienteering were not found in the curriculum, and education on guidance and defense used in orienteering was simple in social studies. The purpose of this study is to develop an educational programme using outdoor orienteering to develop the spatial abilities required for earth science. Therefore, to let students improve and use spatial ability while orienteering, basic skills that are needed to orienteer, such as using maps, compass, and navigate were taught. Six classes were held with various topics and contents, and each class included indoor activities and outdoor orienteering activities using the same contents. Indoor lessons were mainly held in classrooms and computer labs, while outdoor orienteering activities were conducted on a university campus in a group of 2-3 people. Class topics and contents that are already included in the curriculum, such as map, compass were utilized in the programme. Also, this programme aims to let students learn and use earth science contents. In the context, celestial motions, Stellarium were also included in the programme. These programme development process has undergone several reviews with scientific educators, and the programme has been revised and supplemented accordingly. Based on the relevant curriculum, books, and articles, we extracted learning topics and learning elements as shown in Table 1.

We conducted preliminary tests to examine the spatial ability and orienteering ability of participants. There were two types of pre-test provided: an examination to see their own perception of orienteering ability and an examination to check students' spatial ability. The spatial ability test tool developed by Ju (2008) was used to measure students' spatial visualization, spatial orientation, and spatial relation ability. Test

Table 1. Orienteering Programme Topics and Learning Contents

Class	Topic	Contents	Purposes of each class	Activity
1	Diagnostic test	• Spatial ability test • Orienteering skill test • Outdoor orienteering	• Collect basic information about students beforehand	• Outdoor Orienteering with Maps
	Maps	• Compare the difference between map and reality • See the scale, legend, and bearing charts that appear on the map. • Outdoor orienteering activities using maps	• Learn the basics of essential maps related to orienteering • Utilize spatial visualization ability in the map utilization process	• Outdoor orientation with map and compass
2	Compass	• Knowing the structure and principles of compass • Learn how to use the compass • Outdoor orienteering using a compass	• Learning basic contents about bearing included in spatial ability • Use of direction and sense of orientation included in space directional sense among spatial ability required in compass utilization process	• Outdoor orientation with map and compass
3	Elevation in the map	• Know how to express elevation on a map (contour lines) • Planar data shown on the map Converted into three-dimensional data of reality • Test about contour lines	• Utilizing spatial visualization ability to imagine the height information on a map presented in two dimensions as a stereoscopic reality	• Expressing contours using sweet potatoes
4	Utilization of celestial motions	• Know how to use Stellarium • Explore the bearing based on the movements of various bodies • Interpret and express stereoscopic data of computer plane	• Learning basic astronomical contents necessary for bearing reasoning • Utilizing the ability to visualize spatial information through the activity of displaying stereoscopic computer programme information in stereoscopic hemisphere	• Three-dimensional representation of the plane data using Stellarium
5	Using the Astro Movement/ Orienteering in everyday life	• Outdoor orienteering activities using mobile phone constellation applications • Learn how to orienteer in everyday life such as vegetation, tree rings, shadows, and wrist watches. • Approximate distance using the neck, body size, etc.	• Using the sense of bearing that is included in spatial ability. • Ability to estimate the size and distance included in the spatial relationship ability	• Outdoor orienteering activities using mobile phone constellation applications
6	Post-test	• Spatial ability test • Orienteering ability test • Outdoor orienteering	• Analysis of change of students' spatial ability and orienteering ability compared with pre-test result	• Outdoor Orienteering with materials available in everyday life Estimate distance

Table 2. Spatial ability check items according to spatial ability classification

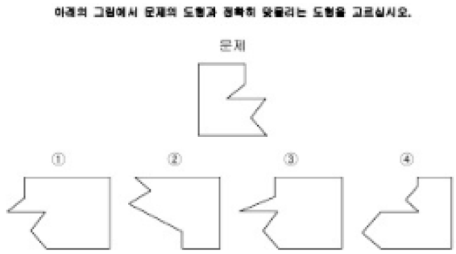
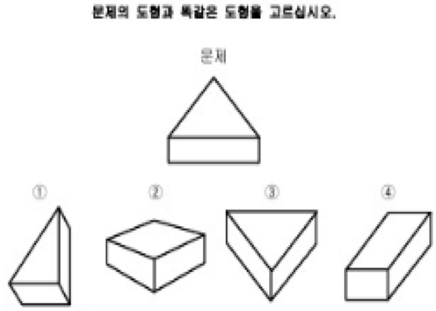
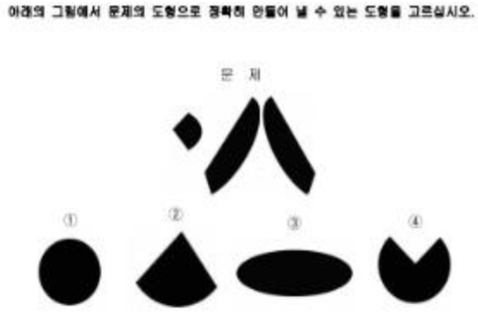
Spatial ability	Spatial ability check item	Number of questions
Spatial visualization	Shape completion	4
	Partial Finding	4
	Planar Figure Folding	8
Spatial orientation	Origami	4
	Completing figures	4
	Night angle projection	4
Spatial relation	Two-dimensional image rotation	4
	Three-dimensional image rotation	4
	Projection	4
Total	40	

items were subdivided into 9 categories, completing figures, projection, two & three dimensional image rotation, planar figure, origami, and etc.

To examine students' perception of their own orienteering ability, test developed by Kwon and Lee (2005) based on the previous research on directional sense and navigation (Hegarty et al., 2002) was used. Skills needed for orienteering, such as perceptual ability, memorizing skill, learning skills were included in the original test, and the total of 28 items were selected through factor analysis. Since the test was developed in 2005, there were some questions that are not adequate for students, such as 'read Atlas well (지도책을 잘 읽는다)'. Also, some questions that are redundant such as 'Sometimes I almost got on a tram going in the opposite direction. (반대 방향으로 가는 전차를 탈 뻔한 적이 종종 있다)', and 'At the subway station, I know the direction in which the subway is coming from my left or my right (지하철역에서, 지하철이 내 왼쪽에서 오는지 오른쪽에서 오는지 그 진행 방향을 알고있다)'.

Some examples of orienteering ability questions are 'In an unfamiliar place, you get confused where east, west, north, and south are (낯선 곳에서는 어디가 동서남북인지 혼동하게 된다)', 'I can see which direction I'm heading on the map (내가 향하고 있는 방향이 지도상에서 어느 방향인지를 알 수 있다)', or 'When changing direction, look at a major building or sign

Table 3. Examples that were included in the spatial ability test

Spatial ability test item	example
Completing figures	
Three-dimensional image rotation	
Projection	

and change direction (방향을 바꿀 때 주요 건물이나 표지물을 보고 방향을 전환한다)'.

Factors extracted here are subdivided into 4 areas: spatial memory and learning ability, sense of direction, and ability to use maps. Students were asked whether they remember the places they visited first, how much they remember the places they visited frequently, and how they can orienteer in a familiar place and etc. How to utilize the map, how to use the information to change the direction, how to use bearings, and whether they were always aware of bearing were also asked.

In addition to the ability tests conducted indoors, we conducted outdoor orienteering activity to see students' pre-outdoor orientation skills. Programme were recorded and analyzed to see how students orienteered and what difficulties they experienced. In addition, students' perceptions to orienteering and their response to orienteering in class after the activity were also examined.

Programme Application

From April to August of 2016, the programme was applied to 5 students in seventh graders in Seoul, also participating in an after-school science class organized every Saturday at a university. Research has been conducted on students who selected the Orienteering Programme among many classes offered in the weekend science programme.

Through preliminary research before the class, we examined students' level of spatial ability, their perception of orienteering, and orienteering ability, then outdoor orienteering activities were conducted. In addition, At the beginning of each semester, students filled out surveys and submitted them to researchers. At the end of the final class, we conducted a final lesson and conducted outdoor orienteering activity using all kinds of materials covered in class. The same questionnaire was used to examine the changes in students' perception of spatial ability and orienteering ability after class. Each classes were recorded, and one assistant teacher watched the lesson and wrote an observation log. After all lessons, individual semi-structured interviews were conducted. All interviews were recorded and transferred.

Data analysis method

In order to derive the research results, we analyzed self - introduction letter, class recording data, students' activity data, interview data, diverse teaching materials that teachers used in class, and research papers before and after class. We conducted pre-orienteering activity to look at students' pre-orienteering methods and abilities before applying the orienteering programme, and post-orienteering to see how students' orienteering methods and abilities changed at the end of the programme. After the class, individual semi-structured interviews were proceeded based on the analysis collected data during the class. Perceptions of orienteering, most interesting and challenging aspects of the orienteering programme, the general questions such as whether there was a change in orienteering method or difficulties, whether or not there were change in orienteering ability were the main questions.

Table 4. Characteristics of participants

Name	Sex	Characteristics
Kim**(A)	F	Introspective and sincere. Not interested in science but receive science tutoring. Participation in group activities is more competitive than indoor group lessons.
Yang**(B)	M	Active, interested in science enough to participate in various science education programmes, competition and Olympiad. Very active in outdoor orienteering activities. Strong commitment and strong physical strength.
You**(C)	M	Feels difficulty in science lessons at school. Has hard times concentrating on a long period of time. More likely to participate if lessons are provided individually.
Lee**(D)	M	Experiences difficulty in science and not interested in science. Prefer outdoor activities rather than indoor classes, but participation in outdoor orienteering activities is not high due to lack of commitment.
Lee**(E)	F	A student interested in science and attending many science programmes. School is good and mainly lead outdoor orienteering activity with A student.

Before starting the class, students' self-introduction and weekend science classroom application were used to identify students' characteristics. After the first class, a test to see the students' awareness of their orienteering ability and their spatial abilities before applying the programme was conducted. The test items for self-awareness of orienteering were comprised of 1-5 Likert scales. In-classroom and outdoor orienteering processes were recorded and analyzed by the researchers. Also, students' earth science content learning abilities were evaluated through the recordings from classes. In this study, earth science content learning ability means how fast and accurately students understand the earth science knowledge that are taught in classroom. Also, these abilities include how well students actually use the knowledge while orienteering outside.

In addition to reviewing the recordings, we evaluated all activities, orienteering accuracy, activity participation, and understandings of students, along with one assistant teacher who assisted all indoor classes and outdoor activities. In order to ensure the reliability of the evaluation results, the assistant teacher and the researcher discussed the criteria to clarify. As a result, the inter-rater reliability of assistant teacher and researcher was about 0.82. After the completion of the programme, students' awareness of their own orienteering ability and their spatial ability were also asked.

Results

In classroom, students translated the materials provided to them in many ways, and efficiently used the transformed materials. Table 4 shows the level of students' pre- and post-spatial ability, perception of their own spatial ability, orienteering ability demonstrated in class, and the ability to learn earth science content in the course. Spatial ability was evaluated by summing up the results of the pre- and post-test. Orienteering ability was based on the results of their classroom activities, ranked by the researchers and the assistant teacher. Students' achievement in earth science was evaluated based on how well students understood the contents of the class and how difficult they felt in the class.

Students' perception of their own orienteering

Students' perception of their own orienteering ability according to their characteristics can be categorized as follows. Students B and E are highly interested in science and generally confident in science subjects. The results of the diagnostic test scored high, and their overall orienteering ability was also high. Students C and D are not interested in science, recognize science as difficult, lack confidence in science subjects, and achievement at outdoor activities were low. Both students had very low self-awareness of orienteering

Table 5. Students' spatial and orienteering ability, and earth science content learning ability

Student	Spatial ability (Quantitative)		Spatial ability rank (Qualitative)	Orienteering ability recognition level (Quantitative)		Orienteering ability rank (Qualitative)	Earth science content learning ability rank (Qualitative)
	Diagnostic test rank (score)	post-test rank (score)		Diagnostic test rank (score)	post-test rank (score)		
A	2 (96)	1 (98)	3	4 (17)	2 (22)	2	3
B	3 (83)	3 (93)	2	2 (18)	5 (17)	3	2
C	3 (83)	4 (73)	4	5 (13)	3 (18)	4	4
D	4 (81)	5 (64)	5	2 (18)	3 (18)	5	5
E	1 (99)	2 (96)	1	1 (30)	1 (28)	1	1

ability in both diagnostic- and post-test. Student A achieved high grade in school science, but does not show a lot of interest or confidence in science. Unexpectedly, the perception of his or her orienteering ability was very positive in both diagnostic- and post-test. As a result of the researcher's evaluation of the activity process, the self-evaluation seems to be more positive than their actual ability.

As a result of the diagnostic- and post-test, students A and E evaluated their orienteering ability the most positively, and then student B followed. All three students were interested in science, had good grades at school, and voluntarily participated in many activities related to science. Particularly, student B and E had very high orienteering ability. These students actively participated in the class and were most active among the research participants working together in the activity process. Students C and D had low academic records, and had difficulties in science classes, lacking interest in science. They also experienced difficulties in understanding the contents of the lesson and using it outdoors during this programme. The results of the diagnostic test of student C and D showed the lowest score for student C in the diagnostic test, whereas the score for student D was the lowest in post-test. This was mainly due to the sharp fall of student D's score. Student D generally had difficulty in orienteering activities and, as revealed in the interviews afterwards, he understood only partial contents covered in each class.

Researcher: Are you guys using the compass?
D: No. We are not using the compass.
Researcher: Why not? Instruction said to use it.
D: It's too difficult to understand.
(Teacher taught how to use compass again.)
(During outside orienteering activity)

This seems to be due to the fact that this student had difficulty with the concept of bearing covered throughout the lesson and continued to experience failure during the orienteering process. This was not expected to be significantly different for student C. Students generally felt that their ability to use maps increased, which seemed to be because they learned a lot about maps and became accustomed to the information system of maps.

Spatial ability that were used in the orienteering activity

Spatial ability is subdivided into spatial visualization, spatial orientation, and spatial relation ability. In this study, we analyzed the spatial ability revealed in the course of the students' activities. First, students were able to orienteer using the ability to manipulate data acquired from outdoor activities in their minds, that is, spatial visualization ability.

C: Doesn't this look like letter ㄱ?
D: Hold on.
C: Isn't it?
D: The roof seems like letter ㄱ on the map. No, it is letter ㅅ.
C: Is it? So it will look like letter ㄱ or ㅅ from the above.
D: Yes. Letter ㄱ or ㅅ.
* *ㄱ and ㅅ are Korean alphabets.*
(During 2nd indoor class)

As shown in the students' dialogues above, students compared the form of the building on the map with the type of the building they actually observed, and in the process of orienteering, they observe the side of the actual building, and imagined what it would look like. In addition to the activities of students C and D, other students also took advantage of this ability in class and activities over several hours.

Converting planar data to stereoscopic data or converting stereoscopic data to planar data is also included in the spatial visualization ability. In the class using Stellarium, students performed the task of displaying the information presented in the Stellarium programme, which is a planar material, in a three-dimensional reality hemisphere. Students expressed the position of the object in Stellarium in the hemisphere, and in this process, they often experienced difficulties.

Students also felt that they needed spatial orientation skills. The spatial orientation is the ability to recognize the object in its position when moving the object or moving the point of view of the object (Kim, 2014).

The students said that it was difficult to use the map because the point of view and the viewpoint of the map did not match in the process of using the map. In addition to spatial visualization and spatial orientation, students were also observed to utilize spatial relationships. Students used maps, compasses, and constellation mobile applications to figure out the location of buildings or structures that they pass by in their quest to find their own bearing.

During the class or in the interview, students were not able to explicitly answer the researcher's questions on how to orienteer. As a result, students did not know exactly what skills they were using to orienteer, but after analyzing their activities, students were using all of their spatial abilities in the orienteering process. Especially, spatial visualization and spatial orientation ability were mainly used among the three spatial ability fields, and the frequency of spatial relation ability to integrate various types of information that are known or collected was the lowest.

The relationship between spatial ability, orienteering ability, and earth science content learning ability.

The evaluation of the students 'activity process in the class is based on the activities of the students and the activity sheets they have created each class, students' participation in the activities, orienteering accuracy, and so on. For the tests conducted before and after the test, the space ability test was scored by setting 1 point for correct answer and 0 point for wrong answer. In order to secure objectivity in the ranking of the activities, all the classes were evaluated on the same basis by the assistant teacher who recorded the activities of the students and observed every classes.

As a result of the diagnostic test of student A, the overall result of spatial ability was low. Student A remained in the middle level, especially lower in the class using Stellarium. The uniqueness of the class using the Stellarium programme is that the information provided in a two-dimensional hemisphere must be displayed in a three-dimensional space. It is interpreted that she experienced difficulties in changing the two-dimensional data into three-dimensional data. In post-test, her spatial ability was the highest among participating students. Comparing the results of the pre-test and the post-test showed a large increase.

Student B ranked high in the diagnostic test. In the classes and activities, he ranked low in the first class using only maps, but he was ranked at the top in the other five classes. On the other hand, post-test results showed the lowest level among the participants. The results of this test are highly contradictory to the evaluation of the researchers, in which he scored the highest level in all classes except the first one due to the high degree of accuracy of the students' understanding of the class and actively utilizing the contents learned during the activity process. Student B was highly evaluated in each class, but had difficulty in using map because he had a particularly low achievement in orienteering class using map at first time.

Researcher: What was the difficult part when you were orienteering?

B: I was confused about east, west, and north.

Researcher: What was confusing?

B: I was a bit confused on the map because it was different from my point of view and reality.

Researcher: So how do you think map differs from reality? It's not the same. Reality is shown on the map, but there's still difference. What do you think that is?

B: The reality is three-dimensional, and the map is flat. And also, the scale is different. The reality is very wide and small on the map.

(During 2nd indoor class)

Student C ranked the lowest among the participants in the diagnostic test. In the following lessons and activities, all of them were evaluated as mid-level except for the first class orienteering activity that used only map, in which he scored the top level. In the post-test, he ranked mid-level. Student C's diagnostic- and post-test results were generally in agreement with the results of the researcher's evaluation of the class and activity process.

Researcher: Now, let's say this is the west side of this hemisphere. So which side is this (pointing the other side)?

B: The west.

Researcher: If that is west, what is this side? Check on the hemisphere you have.

C: East!

Researcher: Is it the east?

C: North.

Researcher: Is it north?

C: I guess it is not the East.

B, D: East!

C: Not the east.

(During 4th indoor class)

The results of the pre-test of student D showed that the middle-level scores were obtained in all the fields of spatial ability and the overall ranking was the highest. On the other hand, classes that were about contours and Stellarium were evaluated moderate, but in other lessons, they were rated low. In the post-test, the mid-level scores were obtained in all areas of spatial ability, and all the scores were in the middle level. In the diagnostic-test, the student's ability to obtain a high overall score in the spatial ability test is contradicting with the researcher's evaluation, compared with the evaluation of the researcher is pretty similar with the post- test result.

The pre-test results of student E were the highest among the participants. Researcher's evaluation of the class were the first or second rank in all classes, which is consistent with the results of the pre-test. Student E did not have any difficulty in understanding the lesson, and she was able to make the best use of the contents learned in the course of activities and to find the destination in the orienteering process. Also, the highest score was obtained from the post-test results.

The results of the study were summarized as follows. First, students' characteristics and the perceptions of their own orienteering ability were proportional to some level with each other. Students with positive attitude toward science and good grades at school were positively evaluating their own orienteering skills. Second, students did not know explicitly what abilities they used to orienteer, but after analyzing the data, it was obvious that they were using all three spatial abilities. Among those three, spatial relation ability was the least used. Finally, spatial ability, orienteering ability, and earth science content learning ability that are presented as Table 4 were all proportional to each other. In all students, orienteering ability and earth science content learning ability were at similar level. It is interpreted that there is a correlation between earth science education and orienteering ability, and it can be understood that spatial ability is cultivated in earth science education as a result of utilizing various spatial ability in orienteering process.

Implications

Except for students' perception of their own orienteering ability, the relation was found in the results of the test scores on spatial ability and evaluation results of spatial ability, orienteering ability, and earth science contents learning ability. Unlike orienteering and earth science learning ability, students' spatial ability is carried out by paper-and-pencil questionnaire, so it was difficult to assure the exact relationship in the other two abilities. However, as the orienteering process takes advantage of multiple spatial abilities, it can be understood that there exists some relation in students' earth science content learning ability and spatial ability. It is expected that students will be more clearly able to show the relation between their abilities by presenting their abilities with specific points or based on clearer criteria. Rather than explicitly showing orienteering abilities or spatial abilities, because it was included in the class and activity process, it was difficult to present it as numerical data. Also, this study categorized students' characteristics and their perception of their own orienteering abilities. Besides the relationship between spatial ability, orienteering ability, and earth science achievement, students' perception toward their own orienteering ability was also changed. Before the class, students often negatively recognized their ability to navigate, which was the greatest improvement in post-instructional use. This is inferred to the fact that students have become accustomed to the way they use maps after they learned how to use maps in class.

Earth science education programme using orienteering has a meaningful result in terms of the integrated education subject and the subject extension which can be covered in earth science. Students considered orienteering to be entirely a social studies subject before classes because they learned the tools used in orienteering, such as maps and compasses, in elementary school social studies class. However, in addition to the contents covered in the current social studies section, such as how to use maps and compasses in classroom, orienteering also contains scientific concepts, such as the principles of compass, bearing through astronomical movement, and bearing inferences through constellation, etc. Through these classes, students' perception changed to thinking that orienteering is also related to science classes. They also recognized that orienteering is helpful in everyday life because it was an ability that should be utilized as usual.

Researcher: Before the class started, what did you think this programme was related to?

E: Social studies.

Researcher: Why did you think it was about social studies?

E: I was looking for a road, because there were a lot of people in elementary school.

Researcher: Did you learn finding a road in social studies?

E: Yes. I think that a little defense has come out of social studies a lot.

Researcher: Then, how come the class is over?

E: I think it has something to do with science, too.

Researcher: In what way?

E: Well, this is a bit of a society or something like that, but I think there was a little bit of scientific principle or something like that.

Researcher: Well, then something seems to have been learned a lot in social studies, but it seems that principles and methods are related to science.

E: Yes.

(During post-interview)

In this study, development and application of earth science education programme using orienteering was presented as a way of improving spatial ability. As a result of this study, students 'orienteering ability and earth science learning ability were found to be somewhat positively related, so it is expected that students will be able to learn earth science by experiencing educational programmes that can enhance students' orienteering ability. Earth science deals with large amounts of time and places, so there is limited data that students can directly experience. However, since the earth science contents included in the recent revised curriculum deal with concepts that require the space capability and bearing in various areas such as solid earth, atmosphere science, and oceanography, development of educational programmes to enhance students' need is required. In this study, the education programme using astronomical contents was mainly carried out, but the development of the orienteering programme using various contents such as geology, the atmosphere science, and the oceanography included in the curriculum would be able to expand the educational possibilities in earth science. It is expected that the results of this study will be used as basic data for the programme development to position earth science as a core subject for students' improvement of the spatial ability in the future.

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