11.5 SNOW CAMP FOR HIGH SCHOOL STUDENTS: FIELD AND LABORATORY STUDIES OF SNOW CRYSTALS

Yukimasa Tsubota*
Obirin University, Tokyo, Japan

Tsuneya Takahashi
Hokkaido University of Education, Sapporo, Japan

1. INTRODUCTION

Japan's Ministry of Education, Culture, Sports, Science and Technology, has been designating high schools that emphasize science, technology and mathematics education as "Super Science High Schools" (SSHs) since 2002. Keio Senior High School was designated SSH in 2003 and has been coordinating strategies with universities and research laboratories. Keio Senior High School's curriculum development theme is the promotion of science learning using earth-space science. Earth-space science attracts young people via its familiarity to daily life. Weather is one of the main topics in curriculum development.

We have planned and carried out three-day snow camps in Mt. Asahidake and at the Hokkaido University of Education where we use the vertical supercooled wind tunnel for studying snow crystal growth for the winters of 2003, 2004 and 2005. A 'hands on' approach is a popular and the preferred method to promote science at Snow Camp. "SNOW" is a familiar topic for students even in Yokohama where snow is not common. The study of snow is important, although we experience snowfall only a few times per year. Cloud Microphysics is the science of cloud processes taking place on the scale of air particles such as cloud droplets, raindrops, snowflakes (snow crystals or aggregates of snow crystals), soft hail particles, and hail particles.

**Corresponding author address:* Yukimasa Tsubota, Obirin Univ., Core Education Center, Machida-shi, Tokyo, 194-0294, Japan;
e-mail:tsubota@obirin.ac.jp

Ice precipitation processes are dominant for rain formation at middle latitudes, even in summer, which means we can see snow crystals in a cloud just a few kilometers above the ground surface where the temperature is over 30 C. It is not easy to observe snow-crystal growth within a cloud, unless one is in the high mountains. We plan to visit Mt. Asahidake in Hokkaido during the school's winter vacation where the mean ground-surface temperature for January is below -10C. Our snow camp's slogan is 'See the Inside of Clouds In Yokohama'.

2. OUTLINE OF SNOW CAMP

2.1 Date and location

Each year our three-day snow camp begins on January 5th, during our winter-vacation period. Selecting an adequate location is very important for a snow camp's success. First, we need to have plenty of snow on the ground. Second, we should have snowfall during Snow Camp. Falling snow depends on constantly-changing weather conditions and orography. Moreover, well-featured single and unrimed snow crystals can be observed in low cloud-droplet concentrations with relatively light wind (i.e. relatively weak convective condition). Snow crystals are rimed in high cloud-droplet concentrations near the seaside. Rimed particles change to soft-hail particles when riming proceeds. The preferred ground-temperature is below –5 C for observation.

Mt. Asahidake was selected for our snow-camp site based on the climatic data as shown in Table 1. The mean snow depth at Asahikawa, the nearest meteorological station, is more than 60cm. We can expect an 80% probability of falling snow, based on the mean temperature and rainfall probability. Our lodge is located on the north-west slope of Mt. Asahidake at 1060 m above sea level where prevailing north-westerlies become updrafts as shown in Figure 1.

Mt. Asahidake is more than 100km inland so we can expect relatively weak convective conditions; and hence, we had falling snow and observed many delicate snow-crystal shapes at our snow camp in 2003, 2004, and 2005.

Figure 1. Location of the snow camp site.

Table 1. Climatic data for January at the Higashikawa Station(43 40.2'N, 142 26.8') and Asahikawa Station(43 45.4'N, 142 22.3'E)

	Higashikawa	Asahikawa
Elevation	211 m	120 m
Mean Rainfall Probability	70%	73%
Mean Temperature	-8.4 C	-7.2 C
Mean Maximum Temperature	-4.1 C	-3.2 C
Mean Minimum Temperature	-13.9 C	-12.2 C
Mean relative humidity	N/A	80%
Mean duration of sunshine	2.1 hour	3.6 hour
Mean depth of accumulated snow	N/A	61 cm

2.2 Time schedule and participants

Snow Camp's time schedule is shown in table 2. We spent two days in Mt. Asahidake in order to study cloud microphysics in a natural environment and one day in a controlled laboratory environment of a cold room at Hokkaido University of Education.

Field science should not expect to get all the necessary data within a natural environment. Researchers may construct a hypothesis based on field measurements and confirm it with further measurements and laboratory experiments. Our snow camp offers students scientific research methods via the experience of such field and laboratory measurements. Students also receive lectures about cloud microphysics and see demonstrations of a supercooled condition of water and do experiments such as freezing orange juice and milk. We also have time to discuss their activities.

Snow Camp's participants are male of ages 16 and 17 years old, for Keio Senior High School is a male-only school. We stayed at a lodge within the Hokkaido University of Education, so students must prepare their own meals, make their beds and do general house-keeping. These activities are considered to be a hidden curriculum within a standard schedule for our snow camp. They also need time for cooking and cleaning as previously mentioned. Times should be varied, based on the prevailing weather conditions. Table 2 is a time schedule for the science activities.

Table 2. A sample time schedule of Snow camp.

1/5 morning	8:00AM Meet at Haneda Airport in Tokyo
1/5 afternoon	Arrival at Mt. Asahidake on 2:00PM, Making Igloo
1/5 night	Observation of falling snow, making replica of snow crystals
1/6 morning	Observation of falling snow, accumulated snow. Experiments with snow
1/6 afternoon	Continuous observation of snow crystals and snowfalls
1/7 morning	Clean up the Lodgings and leave for Sapporo on 9:00AM
1/7 afternoon	Arrival at Hokkaido University of Education on 1:00PM Cold Room Experiment by four small groups and leave for Tokyo
1/7 night	Arrival at Haneda, Tokyo on 8:00PM Dissolution

2.3 Objectives of Snow camp

The snow camps' general objectives are to study the fundamentals of cloud microphysics, field-science methodology, and to experience living in a cold climate. The student's objectives are to:
a. identify snow crystals and soft hail;
b. recall the approximate density of a snow pack;
c. understand how rain develops via observation;
d. explain the fundamentals of cloud microphysics;
e. describe the rain-forming process at middle latitudes;
f. carry out the field measurements;
g. show familiarity with life and characteristics of snow country; and
h. appreciate earth and her ecosystem.

The pre- and post-tests and questionnaires are assigned to all participants in order to evaluate the snow camp.

3. SNOW CAMP ACTIVITIES

Activities include: making an Igloo and learning scientific methodologies such as observing a snow crystal with a magnifying glass; photographing a snow crystal shape via microscope in an Igloo; measuring density, hardness and observing temperature changes in accumulated snow; and doing a snow-crystal growth experiment in a vertical supercooled cloud tunnel. This tunnel can simulate a crystal-growth condition and snowfall within a cloud.

3.1 Igloo making

An Igloo is used as an outdoor laboratory to keep the microscope and other equipment at the same temperature as the outside and sheltered from the snowfall. Otherwise snow crystals could change their shape due to the temperature difference. Igloos are usually built with snow or ice blocks; but our igloo was built by digging a hole in the snow, as shown in Figure 2. A microscope is kept in the Igloo to observe the snow crystals within their environment. An igloo provides the best condition for snow-crystal observation because the air in the igloo is nearly saturated with respect to ice; and hence, a snow crystal can maintain its shape longer as shown in Figure 3.

Figure 2. Igloo making

Figure 3. Microscope observation in our igloo.

3.2 Observation of falling snow

Students use a magnifying glass to observe snow crystals upon a wooden plate covered with black velvet as shown in Figure 4. The suitable magnification is ten to fifteen times. The magnifying grass used here has a transparent skirt as shown in Figure 4.

Figure 4. Magnifying glass and snow crystals upon a wooden plate covered with black velvet.

A student chooses a snow crystal for microscope observation. Snow crystals that were photographed by students are shown in figure 5.

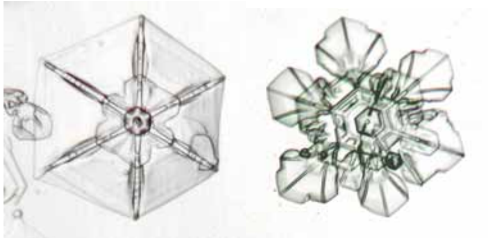


Figure 5. Snow crystals photographed by the students.

3.3 Making a replica of a snow crystal

A snow-crystal replica is a kind of ‘snow-crystal fossil’ and is a popular way to preserve a particular crystal. Snow-crystal replication using the solute of Formvar was developed about 60 years ago by Schaefer (1941). Common plastics are currently used for snow-crystal replication based on the research of Takahashi and Fukuta (1988). Students catch snow crystals on a piece of black velvet, which can be examined to find a particularly-interesting specimen. One can select and preserve several crystals on a single slide. A toothpick is used to apply a drop of cold replica-solution upon a cold glass-slide. The same moistened toothpick is used to gently move the chosen snow crystal. The adhered snow crystal is placed upon the center of the drop. Snow crystals evaporate and leave the snow crystal’s shape that can be observed at anytime and at room temperatures.

3.4 Observation of accumulated snow

Students are to dig a pit in the accumulated snow to observe its vertical cross-section. Then they measure the density, hardness and temperature of the snow per height from the ground surface, and observe the shape of deposited snow particles, as shown in Figure 6.

Figure 6. Digging a pit to have a cross section of snowfall.

a. Layer structure

Sunshine and wind affect the surface of the snow. Therefore, an intermittent snowfall yields a layered structure. Each layer corresponds to a continuous snowfall. Students spray blue ink on the surface and burn it using a portable burner as shown in figure 7. By this method, a striped pattern will appear due to the layered structure of the accumulated snow.

Figure 7. Burning the snow surface to see its layers.

b. Classification of deposited snow particles

A snow crystal changes into a round particle due to the vapor pressure differences based on the crystal's curvature difference. For example, evaporation from a snow crystal accelerates at its protrusions. Snow particles become 'compacted snow' that will be covered with a thin water film due to a rise in temperature, and merged with others to become conglomerates such as "granular snow". Students place a snow sample from each level onto a wooden plate covered with black velvet to study their textures (see Table 3).

c. Measuring snow pack density

An opened cylindrical can is used to measure the snow's density. Snow becomes denser with time via accumulation and changes in the snow-crystal shapes.

The can is inserted into a chosen snow layer and removed with some snow and is weighed. Care must be taken to avoid compressing the snow within the container which would increase its density to give an unnatural measurement. The mass of snow is determined by subtracting the weight of the empty container from the weighed result. The snow density is calculated by mass and volume of the snow sample. Results in 2005 are shown in Figure 8 and Table 3.

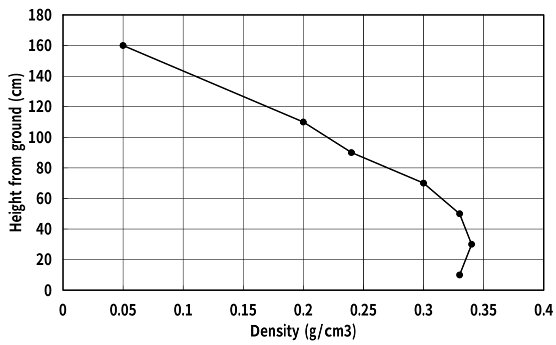


Figure 8. Relationship between snow density and height from ground surface.

d. Measuring snow hardness

Snow hardness changes with time. Hardness is determined with a fist, a finger, four fingers, a pencil and a knife; giving us five categories of snow hardness such as hard, very hard, soft, very soft and so on.

Table 3. Measurements of accumulated snow on the ground (2005/1/16 11:00)

height(cm)		density(g/cm3)	hardness*
160	fresh snow	0.05	
150	fresh snow		fist
140	fresh snow		
130	fresh snow		fist
120	fresh snow		
110	fresh snow	0.20	fist
100	fresh snow		
90	compacted snow	0.24	four fingers
80	compacted snow		
70	compacted snow	0.30	finger
60	compacted snow		
50	granular snow	0.33	finger
40	granular snow		
30	granular snow	0.34	finger
20	granular snow		
10	granular snow	0.33	pencil
0	granular snow		

*Hardness: a fist, four fingers, a finger and a pencil enters into snow, respectively.

e. Measuring temperatures of the snow surface and the inside of accumulated snow

In general, the temperature inside a mound of accumulated snow increases with depth. The temperature near the ground surface should be almost 0C for snow depths greater than 1m. Students measure the snow surface and inside temperatures per height from the ground surface. Daily measurements are done at 11:00, 16:00, 18:30, 21:30 hours and next morning at 8:30.

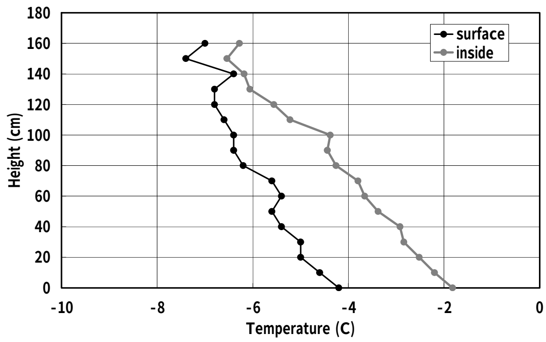


Figure 9. Relationship between surface and inside temperatures of snowfall and height from ground surface.

Temperatures in Figure 9 are average for 11:00, 16:00, 18:30, 21:30 and 8:30 on 2005/1/6 and 1/7.

3.5 Meteorological Observation

Students measure temperature, pressure and ultraviolet radiation A & B at and around the lodge using a Vernier LabPro with sensors. They also take the Mt. Asashidake ropeway to perform these observations at 1100 and 1600m altitudes and measure the snow surface's reflected UV-A and UV-B radiations as shown in Table 4. These measurements where also performed at the Keio Senior High School in Yokohama. They are expected to compare these results.

Table 4. Meteorological measurements on 2005/1/16

	Lodge Inside	Lodge Outside	1100 m	1600 m	1100 m	Lodge Outside
Temperature (C)	25.1	-6.4	-7.3	-11.2	-7.8	-7
Pressure (kPa)	89.33	89.29	86.69	82	68.88	86.57
UVA SKY (mW/m^2)	4.8	42.3	515	1539	548	496
UVA GND(mW/m^2)				712	404	399
UVB SKY(mW/m^2)	17.9	18.9	18.9	47.1	17.2	15.4
UVB GND(mW/m^2)				21.2	15.9	14.9

*Mt. Asahidake Ropeway is used to clime up to 1600m.

3.6 Simulation experiment of snow crystal growth

Controlled laboratory processes are highly advantageous to obtain sufficient knowledge of crystal growth once we understand and mimic the natural processes via field measurements. It is well known that the laboratory study of a snow crystal was pioneered by Professor U. Nakaya at Hokkaido University, 60 years ago. A snow crystal was formed upon rabbit's hair. Unfortunately, the free-fall behavior of a snow crystal during its growth could not be obtained; and hence the heat dissipation from the static crystal and the diffusion of water vapor to it, were different from those of natural snow crystals. It is essential to make a laboratory experiment of snow crystal growth under free-fall. Snow crystals could be grown under free-fall in a static cloud chamber, but the crystal-growth time would not be sufficient.

A vertical supercooled cloud tunnel was developed to allow a snow crystal to be suspended freely and grown by applying aerodynamic mechanisms for horizontal stability. A snow crystal's growth was successfully simulated for up to 30 min by continuously matching the upward-wind velocity with its fall velocity (Takahashi and Fukuta, 1988; Takahashi et al., 1991; Fukuta and Takahashi, 1999).

A wind tunnel has been set in a cold room at Hokkaido University of Education. This experiment corresponds to what we are doing in a gondola suspended on a huge balloon flying inside of natural cloud and watching snow-crystal growth as shown in Figure 10. An example of the snow crystal grown in this tunnel is shown in Figure 11.

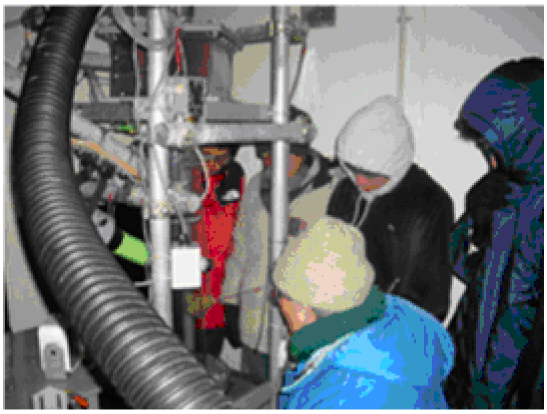


Figure 10. Cold room experiment.

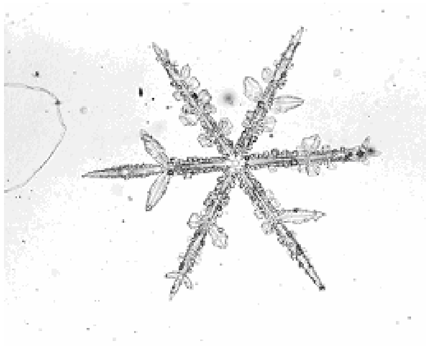


Figure 11. Dendritic snow crystal grown in a cold room experiment at -14.4 C. .

4. PRE- AND POST-TEST RESULTS

We give pre- and post-tests during flights to/from Haneda airport. The contents of the pre- and post-tests are the same. The results are shown in Table 5. Pre-test scores showed similar results and confirmed a lack of knowledge of cloud microphysics. However, post-test scores differ from year to year. That is because the students' motivations differ as the contents of snow camp changes per varying weather conditions.

In pre- and post tests, students are requested to sketch the shape of snow crystals. Some sketches drawn by a student are shown in Figure 12. A drawing of a pentagon-shaped snow-crystal is different from its natural hexagon shape. Actually, no two snow crystals are alike. But snow crystals do show a very limited set of patterns under any particular weather condition. It is also confirmed that students sketched correct images of a typical snow crystal after experiencing Snow Camp. In our snow camp, students are shown that seeing is believing.

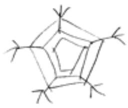
Pre  Post 

Figure 12. Sketches of snow crystals in pre- (Left) and posttest drawn by a student.

Four students had mentioned "snow crystals" to the pre-test question: "What do you expect of Snow Camp?". However, a common answer to the post-test's question: "What is the most impressive event in Snow Camp?", was a cold-climate experience such as 'quantity of snow' and 'coldness'.

All students considered Snow Camp to be 'interesting' with 64% considered the experience to be 'meaningful'.

Table 5. Pre- and Posttest results in 2003 and 2004

Question	2003		2004	
	Pre	Post	Pre	Post
1) How many days of snow do you have in Yokohama on average? a. 0 days b. 5days c. 10 days d. 15 days e. 20 days f. 25 days	45%	55%	0%	18%
2) How many days of snow do you have in Asahikawa on average? a. 31 days b. 51 days c. 103 days d. 144 days	36%	45%	36%	45%
3) How many meters of annual snow fall in Asahikawa. Hint: Annual snowfall in Yokohama is 15 cm. a. 2.3 m b. 4.6 m c. 6.9 m d. 9.2 m e. 11.5 m	73%	100%	18%	73%
4) Please check the shape of snow crystals that we have in natural condition. a. triangle b. quadrangle c. pentagon d. Hexagon e. heptagon f. octagon g. Nonagon	27%	55%	100%	100%
5) Ice doesn't necessarily freeze at 0 C. True or False	27%	45%	82%	73%
6) A snow crystal is produced by freezing a raindrop. True or False	91%	91%	73%	100%
7) A cloud consists of water droplets. True or False	45%	45%	64%	73%
8) Raindrops are formed by condensation of water vapor in the air. True or False	82%	64%	18%	82%
9) Raindrops are formed by collision and coalescence of cloud. True or False	55%	45%	55%	45%
10) The sun approaches the closest point to the earth at the northern hemisphere winter solstice. True or False	9%	73%	27%	45%
11) Water vapor in the air is condensed and form a water droplet and freeze to frost on cooler ground surface. True or False	55%	45%	45%	27%

12) Snow hail particles formed by condensation of water vapor in the air. True or False	82%	73%	45%	55%
13) The snow that has color like red and yellow, etc. can be artificially made. True or False	73%	100%	9%	73%
14) After time passed, shape of a snow crystal will change into spherical. True or False	0%	18%	36%	55%
15) It is usual that the temperature inside of snow cover falls with depth. True or False	64%	73%	91%	91%
16) The temperature of the surface of snow on the ground goes up if the sun shines. True or False	82%	73%	45%	45%
17) The 1m of snowfall has piled in the roof. The load that hangs to the vicinity of roof 1m2 exceeds 1 ton. True or False	100%	100%	27%	55%
18) Let's make snowballs. It is not easy to make it by becoming the low temperature. True or False	27%	45%	82%	64%
19) Who made an artificial snow-crystal for the first time in the world?	55%	45%	64%	100%
20) What was used in order to make an artificial snow-crystal in order to keep it?	18%	82%	45%	100%
21) The person said, "The snow crystal is a letter sent from the heaven". Well, what is it?	55%	27%	73%	100%
22) When the juice and milk are frozen, neither the coloring matter nor sweetness is included in the part of frozen ice. True or False	18%	73%	82%	73%
23) Snow crystals have a character to exclude the foreign body when freezing so the snow crystals are not made acid like rain. True or False	36%	55%	55%	45%
24) The glacier is the one that the snow melts into water and froze again. True or False	73%	55%	64%	45%
25) The drift-ice in the Sea of Ohohtuk is the one that the iceberg in the Arctic Ocean had flowed. True or False	36%	45%	36%	45%
26) The ratio where the temperature goes up in the morning almost equals the ratio that the temperature falls at night. True or False	45%	100%	55%	45%
27) Relative humidity is high in the morning and falls during daytime and again becomes high in night even in the snow country. True or False	64%	100%	27%	45%
28) The temperature has the change in about 5 C every an advanced difference 1000m in the vicinity of surface of the earth. True or False	64%	45%	55%	27%
29) The atmospheric pressure has change in about 100 hPa every an advanced difference 1000m in the vicinity of surface of the earth. True or False	64%	64%	73%	55%
30) After the sunrise, the lowest temperature is observed. True or False	45%	27%	64%	64%
Average	55%	67%	52%	62%
Standard Deviation	27%	27%	25%	24%
Maximum	100%	100%	100%	100%
Minimum	18%	9%	0%	18%

5. SUMMARY

We have developed a snow-camp program for high school students and carried out three-day snow camps to promote science in Mt. Asahidake and at the Hokkaido University of Education where we used the vertical supercooled cloud tunnel for snow-crystal growth study for the winters of 2003, 2004 and 2005.

We cover the science and the experiences associated with snow. The science of snow is very important to decipher the secrets of meteorology; such as learning how snow formation is associated with middle-latitude precipitation. Life with snow gives us some wisdom to live in harmony with nature. Snowfall is a very important water resource for our agriculture and daily life in Japan. Therefore, our snow-camp experience is beneficial to our students, even in Yokohama where we have few days of snowfall per year.

Our snow camp's slogan was chosen to be 'See the Inside of Clouds In Yokohama'; where the high school is located. We apply 'hands on' techniques to study cloud microphysics described in this report. Planning science activity in the real world is not an easy task but the effects are promising. We should continue to provide this kind of activity to stimulate the student's curiosity.

Acknowledgements

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