Logbooks and Journals: Using Historical Materials in School Science

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ABSTRACT. Science education is believed to be a process of enculturation into the scientific community. Learners in apprenticeship roles are introduced to the knowledge of science and to the scientific community's purposes, ways of thinking and acting, style of discourse, codes of behaviour, values, history and traditions. The guide, like an "old-style master craftsman", leads by example. Classroom teachers in the first six years of formal schooling may not feel sufficiently acculturated to act as guides helping children to understand these concepts, symbols, conventions, and discourse practices. Using the logbooks and journals of whaling captain William Scoresby, Junior, in the context of the research begun by Palinscar, Ford and Magnusson, it will be shown that such historical materials can assist teachers and learners in attaining a number of these goals.

Introduction

This paper brings together the work of three research projects in an attempt to design a curriculum that builds upon what is currently believed to be the purpose of science in primary and secondary education, and how this purpose is best achieved with young learners. It begins with a review of the aims and means of teaching science between 1955 and 2006. This is followed by a short description of Seatter's distinction between the facilitation of learning that is perceived as strategic teaching acts and facilitation that focuses as much on intellectual teaching acts as those that are strategic. A clear example of the latter is provided using the published works of Annemarie Palinscar with Danielle Ford and/or Shirley Magnusson. This leads into a description of what might be possible if the journal and logbook entries of a scientist are used in place of the invented scientists in the curriculum created by Palinscar and her team. The scientist is Arctic whaler William Scoresby, Junior (1789 – 1857), and the cited logbook and journal entries are associated with his study of snow crystals while whale fishing in the Greenland Sea between 1807 and 1820.

Science Teaching (1955-2006)

Scientists, science educators, and science teachers have been fine-tuning science teaching since the mid-1950s. Nineteen hundred fifty six is the year the Physical Science Study Committee (PSSC) established by a group of scientists and high school teachers at the Massachusetts Institute of Technology received funding from the National Science Foundation (NSF) to develop a new and improved high school physics course. This led to the publication, in 1960, of the first edition of *PSSC Physics*, and by 1964 university/college-level scientists were directing twenty different NSF curriculum reform projects in the United States (Klopfer & Champagne, 1990). In each case, whether designed for secondary or elementary classrooms, the goal was to bring students "into contact with scientists' approaches in investigating the natural world" (Klopfer & Champagne, 1990, p.145): "to present the sciences as systems of inquiry rather than simply bodies of knowledge…and to learn the science by developing, so far as possible, the view points and modes of attack of scientists confronting problems" (Gatewood & Obourn, 1963, pp. 361-362). Science teaching was to move out of textbooks and into the laboratory.

It was understood, particularly by Robert Karplus, the theoretical physicist directing the elementary-level Science Curriculum Improvement Study (SCIS), that inquiry in school science involved more than curiosity, interesting problems, investigative experiences, and interpretation of observations in vernacular language. Such spontaneous learning, limited by the child's preconceptions, was known to develop commonsense viewpoints incompatible with modern scientific concepts (Jacobson & Kondo, 1968). To effect a transition from student's science to scientists' science, SCIS aimed to turn the classroom into a laboratory where basic scientific knowledge, investigative experience, and curiosity could be "integrated, balanced and developed through the children's involvement with major scientific concepts, key process-oriented concepts, and challenging problems for investigation" (SCIS, 1970, p. 8). Thus, learners in these classroom laboratories were to be given access to both experiences and the concepts and models of conventional science. Teachers were responsible for helping learners to realize that observations and interpretations could be understood in a different, more generative way, and to provide the necessary conceptual framework and application activities to stimulate each child's further cognitive development. Failing to provide such interpretive constructs was known to result in the haphazard development of scientific concepts and the generation of invalid generalizations that acted as "serious obstacles" to each child's ongoing learning in school science (Karplus, 1964, p. 296).

The extensive research begun in the late 1970s on children's ideas, meanings for words, and informal theories about natural phenomena transformed the way teacher educators and teachers conceptualized and justified learners' involvement in an instructional period of open-ended, exploratory investigation (as SCIS had been designed to do). Rather than focusing only on the need to provide common, concrete experiences that begin building (or developing, as would be the case for spiral curricula) concepts, skills, and attitudes, it was believed necessary to plan these exploration opportunities in light of children's informal knowledge and underlying beliefs. Simply teaching the scientific perspective, even when this was introduced to order learners' exploratory experiences, seldom guaranteed the acquisition/construction of scientific knowledge. In fact, children's conceptions were found to be so entrenched and resistant to change that the scientist's viewpoint often appeared unbelievable and irrational or was misinterpreted to substantiate existing ideas (Osborne, 1985). As a consequence, the meanings generated in science lessons were revealed to be idiosyncratic (Cleminson, 1990; Chinn & Brewer, 1998; Gilbert, Osborne, & Fensham, 1982; and Hodson, 2001) and "vastly different from those intended by textbook writers or teachers" (Freyberg & Osborne, 1985, p. 88). Constructivist learning theory helped to explain the dilemma in which science educators and teachers found themselves. However, eliciting learner's ideas and beliefs and designing lessons in which small and large groups of learners explored, tested, and then questioned their existing understandings in light of formal science alternatives did not often result in the cognitive dissonance and revision anticipated. It was at this point that science educators began looking to the history and philosophy of science for guidance.

Richard Duschl (1985,1988, 1990) and Derek Hodson (1985, 1988) were two of the first science educators to look back over the NSF curriculum projects and describe the consequences of having failed to incorporate developments in the history of science and the philosophy of science. Duschl argued that science education was adopting new perspectives for the teaching of science as inquiry at a time when the basic definitions of scientific inquiry were being altered by a move to a new philosophy of science in the 1950s and 1960s. Historians and philosophers Thomas Kuhn, Imre Lakatos, Larry Laudan, and Paul Feyerabend either rejected or put into serious doubt the standard empiricist view of the scientific enterprise. Empiricists believed that nothing enters the mind of the scientist except by way of sense data that impart a true and faithful record of the world, that the validity and reliability of observation statements can be readily confirmed by other observers, that scientific laws are derived by a process of induction from empirical inquiry (the "facts" of sense data), and that science grows in a cumulative fashion by adding to what has been observed and in doing so progressively reveals the truth about the world (Driver, 1994; Hodson, 1998; Kourany, 1987; and Monk & Dillon, 2000).

Hodson found that the empiricist view permeated the curriculum documents with "too much emphasis on inductive methods, a too-ready acceptance of an instrumentalist view of scientific theory, a serious underestimate of the complex relationship between observation and theory, and a neglect of the activities of the scientific community in validating and disseminating scientific knowledge" (1988, p. 22). The new philosophy did not regard science knowledge as "absolute truth ascertained by value-free, disinterested individuals using entirely objective and reliable methods of inquiry" (Hodson, 1998, p. 17). Using the philosophical arguments put forward by Kuhn and others, science educators were quick to point out the fallacies embedded in school science curricula, particularly notions of what science is[i]. Key factors in the failure of the NSF projects to enhance children's scientific understanding were thought to be the following: (*i*) Teaching that treated discovery as testing and proof (*ii*) a generalized scientific method; (*iii*) content-free science processes and problem solving activities; (iv) the priority of observation over theory; (*v*) theory as simple guesses; (*vi*) and the subordination of theory to experimentally gathered "facts" (Abimbola, 1983; Cleminson, 1990; Driver, 1994; Duschl, 1988, 1990; Finley, 1983; Hodson, 1985,1988; Millar, 1994; and Millar & Driver, 1987).

The processes used by teachers to assist learners in constructing and reconstructing conceptions were seen by many to be analogous to Kuhn's periods of normal and revolutionary science (Anderson & Smith, 1987; Carey, 1985; Confrey, 1990; Duit, 1991; Duschl and Gitomer, 1991; Glynn, Yeany, and Britton, 1991; Novak, 1993; Nussbaum, 1989; Posner, Strike, Hewson, & Gertzog,1982, Villani, 1992; Vosniadou & Brewer, 1987). A difference, of course, exists: the scientist is educated and trained within the current paradigm and becomes a member of the scientific community while the young student in school science has learned to see the world as it is understood by those around her and this practical, culturally safe, commonsense understanding is "largely built on out-of-date science" (Claxton, 1993, p.197). Rather than continuing to teach for radical conceptual change and the exchange of commonsense beliefs for science conceptions, educators began to see learning and cognition as situated, and the domains of knowledge as cultural enterprises, sociocultural contexts, communities of knowledge, or sub-cultures within a larger culture (Brown, Collins, & Dugiuid, 1989; Cobern & Aikenhead, 1998; Costa, 1995; Driver, Asoko, Mortimer, Leach, & Scott, 1994; Duit & Treagust, 1998; Pea, 1993; Pomeroy, 1994; The Cognition and Technology Group at Vanderbilt, 1990). Such a view made it possible to think of science teaching as "a process of enculturation" (the cultural transmission of a sub-culture) and learning as acquisition of the attributes (tools or resources) of a sub-culture (Driver *et.al.*, 1994, p. 7). These attributes included knowledge, styles of discourse, ways of thinking, conventional actions, beliefs, symbols, codes of behaviour, practices, values, material artifacts, technological know-how, history, and world view (Cobern & Aikenhead, 1998).

In this context, it wasn't necessary for learners to relinquish or overwrite the conceptions they valued and found useful in everyday contexts; "Human beings take part in multiple parallel communities of discourse, each with its specific practices and purposes" (Driver *et.al.*, 1994, p. 8). Learners merely had to learn to navigate between cultures and sub-cultures, to have the capacity and motivation to participate in these sub-cultures, and to draw upon the appropriate attributes and use them as those in the culture or sub-culture would use them (Cobern &

Aikenhead, 1998; Hodson, 2001). Attributes of sub-cultures were to be learned in apprenticeship with teachers, already acculturated, who modeled expert practice and provided opportunities for participation in authentic tasks where the skills of metacognition and critical reflection were utilized. Learning in science, as a consequence, was to be "inquiry-oriented, personalized and collaborative, and conducted in accordance with the norms and values of the community of scientists, under the guidance of a skilled practitioner" (Hodson, 1999, p. 246). At least, this was the vision of those advocating what has been called, "the modernist view" (Keyes, Hand, Prain, & Collins, 1999, p. 1067). Postmodernists preferred that students not be "inducted" into the community of scientists and scientific ways of seeing: Science education was to make possible a critique of the scientific enterprise with its dominant Western view (Prain & Hand, 1996). More recently, others informed by cross-linguistic research have argued for a communicative focus grounded in language and language arts (Andrerson, 1999; Hand, Prain & Yore, 2001; Hand, Alvermann, Gee, Guzzetti, Norris, Philips, Prains, & Yore, 2003; Norris & Phillips, 2003). They see reading and writing as being "inextricably linked to the very nature and fabric of science" and, thus, "proper science learning" and aim to increase the variety of language practices (speaking, listening, representing, interpreting, writing, and reading) in science courses at all levels (Norris & Phillips, 2003, p.226).

For those whose careers as science teachers and science teacher educators spanned the forty years between 1955 and 2004, one wonders if there is anything that remained constant. In light of what appears as continuous review and transformation, what ought teaching be? More importantly, what should be the content of science teacher education programs, given that future teachers enrolled in educational policy, educational psychology, and teaching methods courses work within and across "domains" of knowledge[ii] that are designed to help develop habits of mind, intentions, actions, and ways of thinking about educational contexts, students, incidents, and the teaching-learning process (Richardson, 1999)? Are there successful teaching acts that endure the chaotic system that formal education gives the appearance of being? For the first six years of school, there may be. These acts of teaching, as defined by Seatter (2003), are both intellectual and strategic and, as will be shown, are well represented in the work of Annemarie Palinscar and colleagues at the University of Michigan.

Science Teaching (Grade 1 – Grade 6)

Strategic teaching acts are teaching activities that "provide a structure for a productive learning environment" and "involve strategies for bringing about learning" (Seatter, 2003, p. 69). They are psychological or facilitative and, as Seatter makes clear, "include all of the preparation and presentation revolving around the learner". In curriculum documents and texts on teaching, strategic teaching acts are generally represented under headings similar to the following: classroom climate; classroom rules; procedures and routines; material environment; physical facilities; safety; teaching aids; engagement; orientation; activation; and motivation. Intellectual teaching acts include all of the preparation and presentation around the concepts a lesson is designed to teach (Seatter, 2003, p. 70). As such, these teaching activities tend to be more focused on the subject matter than the learner and can be identified as the components of good planning and teaching presented in publications like the National Research Council's "Science Teaching Standards" (1996, pp. 17-53); Stevenson's "Developmentally Responsive Pedagogy" (2002, pp. 123-171); and Wellington's "The Art and Craft of Science Teaching" (2000, pp. 3-23). Seatter draws upon the work of R. F. Dearden, Michael Matthews, Joan Solomon and others to claim that strategic acts are the fundamental practices associated with “facilitating” (as opposed to instructing) in many constructivist classrooms in spite of the fact that theoretical concepts are seldom formed through perceptual and practical experiences; they “are inherent in intellectual teaching acts only” (2002, p. 75). She argues that learning science cannot occur as a result of facilitating alone, and writes:

> Theoretical concepts are those science ideas which are not learned on one’s own; they are those which require teaching. In order to grapple with such concepts, a teacher, to be teaching science, must implement the intellectual acts of teaching – those teaching acts which stimulate children to question and look for reasons within the tradition of scientific inquiry (2003, p. 84). To limit one’s preparation to strategic acts is to marginalize the importance of the content of science phenomenon under study and the nature of scientific concepts (2003, p. 80).

The published studies of Palincscar & Magnusson (2001), Magnusson & Palinscar (1995), and Ford, Palinscar, & Magnusson (2000) describe science teaching that is designed to assist children in constructing alternative, scientific interpretations to those provided by their everyday experiences and common sense. A synopsis of their descriptions of a teacher and learners studying light in a Grade 4 classroom will be used as an example of substantive intellectual teaching acts that are supported by strategic teaching activities. Before relating the Grade 4 study, it’s important to note that the initial phase of their research program attempted to answer the question, “What does the interplay of first- and second-hand investigations look like when a class is using nonrefutational expository text?” The study developed to answer this particular question was carried out with a Grade 3 class. It began with students generating a list of what they collectively knew about light and using the list to construct a set of investigable claims. Then, pairs of students selected two of these claims to investigate using light boxes and an assortment of teacher-provided materials. Collected data was recorded in notebooks by each student pair and presented to the other members of the class over a period of several days. Following this week of first-hand investigations, no science instruction occurred for a week and a half. During this time, the research team created an expository text that incorporated the students’ investigative experiences and made use of the established vocabulary and familiar light concepts. The teacher began the text-based segment of her teaching, what Palinscar and colleagues refer to as “the second-hand investigation”, with the construction of a student-generated list of claims that they either hadn’t been able to investigate with the available materials or hadn’t collected sufficient evidence to permit acceptance or rejection. The transcript of the dialogue associated with the suggested entries for the list is a focused and thoughtful exchange between the teacher and the students and the students with each other. This is a consequence of the teacher’s questioning and probing for the information written in their notebooks, and students’ recollections of the sometimes-controversial results shared in the presentations. After collecting and listing nine under- or non-investigated claims, the teacher read a short section from the researchers’ created text[iii]. As with all passages that followed, examples were requested, questions were posed, concepts were clarified, and the students were expected to compare the statements in the text with the claims they had investigated. There were also opportunities to summarize the content of the passage, to predict, and to agree or disagree with a claim given what had been read (the reciprocal teaching strategies of Palinscar and Brown, 1984). At the end of the study, it was determined that the text provided a shared context that enabled the students to “advance their consideration and judgment regarding a common set of claims” (Palinscar & Magnusson, 2001, p. 173). However, the information as presented in the text had not encouraged the students to learn, think, and reason scientifically, nor had the students been helped to assume a critical stance in relation to the text (Palinscar & Magnusson, 2001, p. 173).

In light of the outcomes, the research team began designing texts that would continue to integrate with guided inquiry teaching and also promote scientific literacy, in both its fundamental and derived interpretations (Norris and Phillips, 2003). In addition, they planned to free the teacher of some of the instructional tasks associated with the use of text as second-hand inquiry by subsuming teaching of the expert's conceptual and syntactic knowledge of science in the narrative and structural features of the text. The decision was made to model the text on a scientist's research notebook and to have the scientist investigate the same topic/subject matter the students were to learn in science. The simulated notebook in the Grade 4 study described below incorporated exposition, narration, description, and argumentation and was regarded as a think-aloud by Palinscar & Magnusson (2001, p. 174). They write:

> Lesley…[the scientist narrator] documents the purpose of her investigation, the questions(s) guiding her inquiry, the investigative procedures in which she is engaged, the ways in which she is gathering and choosing to represent her data, the claims emerging from her work, the relationships among these claims and her evidence, the conclusions she is deriving, and the new questions that are emerging from her inquiry (2001, p. 174).

Thus, the text featured several ways of representing data and incorporated reference material utilized by the narrator that would either corroborate or call into question her results and had the narrator modelling strategies for reading and interpreting published research so that the information could be used to formulate claims to advance an inquiry. Built into the "story" was also an interaction between the narrator and other scientists that focused on methodology, data interpretation, and the nature of evidence (Ford, Palincar, & Magnusson, 2000, pp. 3 and 6; Palinscar & Magnusson, 2001, pp. 174-175). A one-page excerpt from this notebook is appended (see Appendix 1).

Ford's dissertation study, in which this text was used, had been designed to answer the question, How does the integration of text use into inquiry instruction contribute to the development of students' syntactic understandings, particularly the understanding of data as evidence? (Ford et al., 2001, pp. 3-4). As in the Grade 3 study described above, the curriculum content dealt with the concept of light. The lessons, however, did not begin with a one week investigation of an assortment of claims based on the student's untutored knowledge and understanding of light. Three focus questions guided the teaching and learning of three topics, namely: the interaction of light with materials; the reflection of light from a mirrored surface; and the relationship between light and colour. Ford began her seven week study after the teacher, Ms. Lacey, had completed several small units on buoyancy and classification. This was Lacey's attempt to acquaint students with the process of inquiry science and the language associated with the three phases as she saw them represented in the first-hand investigations planned by the research team (e.g.: claim, statement of what is believed to be true; evidence, collected data that helps to decide the accuracy of claims; and conclusion, determining the correspondence between the evidence and a claim and offering an explanation). Claims, in this context, were considered to be theory-like, and the children's task, albeit at a much more elementary level, was not unlike a scientist's attempt to coordinate theory and available evidence (Ford et al., 2000). Although such an approach could be faulted on its empiricist/inductivist philosophical stance, as claims emerged from observations and were modified or dropped as data were collected, this is not a problem of which the team was unaware. They understood that "conceptions are guiding principles of inquiry, not its immediate fruit" (Schwab, 1962, p. 198). Their purpose, however, was to study teaching aimed at developing understandings of legitimate and precise data, the representation of data, and the notion of data as supporting evidence using first-hand investigations and expert knowledge embedded in text.

The students began the light unit with a two-week investigative cycle. Using flashlights and twenty-eight materials they were asked to observe and record the behaviour of light as it came into contact with each material and to look for and identify patterns associated with light absorption, reflection, and transmission. In the beginning, shared results generally corresponded to the three components of investigation (claim, evidence, conclusion) where evidence was construed as methodology (what was done) and written visual information (what was seen to have happened). Through guided questioning and conversations with the students as each investigation was presented, the teacher emphasized the importance of collected evidence over non-testable beliefs, suggested the use of drawing as one way of presenting data as evidence, and pointed out how unconventional methodologies could affect data interpretation (e.g. the materials were taped to a screen making it impossible "to see what happened to the beam of light on the other side" (Ford et al., 2000, p. 10). In the second week, students were only allowed to present their "research' if they had evidence to support their claims. It was noticed that several students had described qualities of the light (e.g. brightness) or represented pictorially the relative amounts of the light from the flashlight reflected or transmitted by a material (thick and thin lines). The research team interpreted this as coming to recognize "[t]he need for precision (in order to facilitate understanding)" (Ford et al., 2000, p. 11).

The notebook text was introduced in the third week. The students for the first time encountered research data in tables and conclusions (claims) in bulleted lists. Learning how to read and interpret the data table required "strong scaffolding by the teacher and text" and "intense discussion" (Ford et al., 2000, p. 12). Understanding the bulleted statements as claims and identifying the data (evidence) that supported each claim was equally demanding as the following excerpt from Ford and colleagues' 2000 paper illustrates.

> After establishing what this section of the text was (a claims list), Ms. Lacey then asked students to identify the evidence that supports each of the claims. Students had trouble locating this information. While the evidence is located in Table 1, on page 1, the students looked all over the page they were on, or provided evidence from their own experiences. A lengthy conversation ensued in which students struggled to identify evidence for the claims. Finally, Talia pointed correctly to the precise data in Table 1 that is indeed the evidence for the first claim.

During the forth week of the study, the students were to use the results from the investigations carried out in first in first two weeks to construct a class table identical to a table in the notebook text. This began as a worksheet activity. That is, a single worksheet was filled out during each presentation, and, at the end of all presentations, the data on these worksheets were used to fill in the class table. The research team noted the appropriation of text representation formats into the presentation posters. Drawings were more precise, reflected and transmitted light lines were standardized, numbers [qualitative] were assigned to each phenomenon, and a few groups used diagrams with mini-tables (Ford et al., 2000, pp. 14-15). The class table was put to use in checking the claims that had been made; was there evidence to support each one.

In the final weeks, the students investigated the reflection of light from mirrors. Ms. Lacey focused her instruction on the need for precise data and its clear and accurate organization in tables and figures. The success of her teaching is captured in the following passage:

> Because of the public sharing phase of the instruction, in which students discussed their results in a whole group setting, there was a real purpose for drawing data as accurately and clearly as possible, and for the use of that data as evidence to be convincing to others. Students struggled with this need, and how these representation standards changed over the course of the program of study. However, they successfully developed a shared discourse around representations, as evidence by the dropping away of intense focus on the mechanics and parts of drawings and increased focus on the support of claims from that evidence (Ford et. al, 2000, pp. 18-19).

The teaching that the research Palinscar, Magnusson, and Ford enabled is a sequence of intellectual teaching acts. The teacher in both studies works continuously in the zone of proximal development in an effort to bring about the learning, at a rudimentary level, of what Schwab (1978) refers to as the discipline specific skills that a curriculum could impart. These are "the skills by which one applies the truths learned from a discipline", "the skills of enquiry", including the skills of secondary enquiry ("learning the structure by study of instances of it)", and "the skills of reading and interpretation" (pp. 236-237). I can think of no other reports where an attempt has been made to develop, even though unequally, all three of these skills in lessons designed for children in elementary schools. One wonders what the consequences might be if the syntax of the discipline is learned as one learns the knowledge; when the knowledge is taught both in the context of the conceptions and data that determined its meaning and conferred validity (Schwab's enquiry into enquiry using historical data as the source) and through guided first-hand investigations. Palinscar and colleagues have hinted at such an approach with their invented notebook of science and its use in inquiry-based instruction where the teacher is the expert pedagogue and the attributes of the scientific community are represented in the fictitious scientist whose notebook is read and interpreted. The final section of this paper will look more closely at the use of historical journals and notebooks in lessons that aim to develop understanding in and about science.

Historical Materials in Science Teaching: The Logbooks and Journals of William Scoresby, Jr.

The informal writing of William Scoresby, Jr. (1789 to 1857) is used as the example in this paper for no reasons other than his logbooks and journals are available in the Whitby Literary and Philosophical Society and his prose is engaging and accessible to adolescent readers. As an early nineteenth century whaler-scientist-explorer, Scoresby, like so many others in this period before the Industrial Revolution, investigated and wrote on diverse subjects of interest. For Scoresby, these included topics specific to his work while at sea for 21 seasons in the whale fishery and topics more aligned with describing and explaining what he had the opportunity to observe in the late spring, early summer arctic environment. The former includes his writing on the Greenland whale and the Northern whale-fishery, the green coloured seas in which whale-fishing was consistently profitable, ocean waves and currents, the variation in chronometers and compass needles onboard sailing ships, polar ice and polar fog, and the "tooth" of the narwhal. In the latter category, one finds journal entries, public lectures, and publications on the following: atmospheric refraction; *Aurora borealis*; vanished Norse settlements along the coast of west

Greenland; lightning and electromagnetism; mountain echoes; the temperature and pressure of the Greenland Sea at various depths; magnetism and magnetometers; the prismatic colours of rainbows and dew drops; and the northwest passage and Franklin's expedition. From the age of sixteen, Scoresby also studied snow crystals, and it is this work that will be the material discussed in the present context of classroom use. Snow is a topic that fits well with weather units in middle years science. It could also be adjusted for use with young children learning about the air and water in their immediate and local environments or learning about the characteristics that distinguish the seasons in regions where snow is a common form of precipitation.

On the twelfth of March in 1803, at the age of thirteen, Scoresby became indentured to his father, a distinguished whaling captain, for a period of seven years. In 1806, he advanced to the position of Chief Mate on the whaling ship *Resolution* commanded by his father, and it is in this position that he began maintaining the ship's logbooks (Jackson, 2003, p. *xxvi*). The logbook was essentially a daily register of a whaling ship's course during the five months of whale-fishing in the northern seas and oceans. Entries were to include location (latitude and longitude) and distance travelled, wind and weather conditions, land sited and the correct bearings and soundings and supposed distances from other known land masses, and the time and latitude in which any creature from the sea was killed, taken, or caught by the ship's crew (Jackson, 2003, pp. *xxii* and *xxiii*). The careful recording of this information was a requirement imposed by the British Parliament on the commanders of British whaling ships. To collect the bounty that was based on a ship's tonnage of whale blubber at the end of a voyage, the logbook had to be turned over to the Collector of the Customs at a British port of entry. It was also necessary for the commander and the chief officer, in the presence of the Collector, to jointly and then separately "verify on an oath" the contents as written (Jackson, 2003, p. *xxii*).

Initially, Scoresby's daily entries were like those immediately below, which are excerpts from the *Resolution*'s 1807 and 1808 logbooks.

> Sunday May 10 NNE
> 8 am Therm: 19° Bar: 29.80
> Lat. 75° 30' Lon. 7°10' E
> Strong breezes & cloudy with showers of snow. The ice opening to the E.ward sailed in a little way, then turned to windward, saw several fish, had three boats away, but could not get fast. About mid p[ar]t day too & so continued, sometimes sailing to & fro amongst steams of ice under an easy sail (Scoresby, 1807).
>
> Monday May 2 ESE to S
> Lat. 76° 50' L. 8c 40' S
> The fore part strong gales, with snow; the middle part inclinable to calm with constant snow. As by the barometer we did not expect the gale to abate and did not make any more sail. The latter part clearing up, it began to blow very hard. At noon more moderate. Saw several fish, sent two boats away & J[oh]n. Askew struck one which we lost.
> Bar. 29.50, Ther. 28° (Scoresby, 1808).

The first indication that Scoresby saw snow as more than simply meteorological data to record for the Collector of the Customs occurs in the entry for Saturday, April15th during the 1809 voyage. He wrote:

> NE E
> Lat. 72° 40' Long. 4°50' E

> Effects of bay ice or sludge in smoothing the sea [in left-hand margin]
> Strong breezes or fresh gales, all the day’ sailing by the wind to the NE passing thro’ streams of washed ice, or patches of bay ice, until about 9 P.M. when coming amongst ranker ice tacked and plyed to windward, with the wind at E on NE chiefly amongst bay ice. Several sail in sight. Observed several remarkable crystals of snow, of uncommon regularity, and beauty, and made drawings of them. It is surprising to observe the effect of the young ice, however thin, in smoothening the sea. It does not diminish the swell very materially, but it removes all the wind lipper [spray] and prevents the sea breaking so that in the hardest gales scarcely a drop of water comes on the ship’s deck (Scoresby, 1809).

Eight days later, on Sunday, April 23rd, Scoresby’s snow crystal observations resulted in what science educators would call a productive question; one that leads to a first-hand investigation. Among other events, he noted the following:

> …About 9 P.M. the thermometer being at 27°, and the barometer 30.46, wind west a fresh breeze, and cloudy, we had showers of snow of the prismatic form 1/8 t 1/16 of an inch in length, without any admixture of flat crystals. How does [sic] the different crystals depend on the temperature, pressure, wind, or any other particular state of the atmosphere? At any one time there are great varieties of form, but certain kinds such as large rough flakes, prismatic snow, or fine delicate crystals occur at different temperatures; the two former only when the temperature is mild, or near the freezing point (Scoresby, 1809).

It was at this point that he began the more thorough and systematic recording of his observations, along with the required meteorological data, to determine whether a relationship existed between the morphology of an individual crystal and conditions of the atmosphere in which it was produced. Scoresby’s entries for Saturday, April 29th and Monday, May 1st included the excerpted passages transcribed here:

> …In the evening a little snow fell flat, thin, & regularly crystallized. I am inclined to think that the greater the degree of cold the smaller, more delicate, and the more perfect are the crystals. For example, April 25, 26, 27,28, therm. 37°, 32°, 30°, snow uncrystallized or opaque hail. In the morning the thermometer falling to 19° the forms of snow were changed from a flat to two flat stars, joined by their centres by an opaque piece of cylindrical or prismatical snow like the wheels of a coach or carriage connected by the axle (the wind then at E); others were flat stars with and opaque piece of ice rising from their centres; others were crystallized in a perpendicular direction as well as longitudinal; spines in every direction, springing from an opaque centre, a little similar to the Chevaux de friez. I found one with only three points but whether the other three were broken off I know not: 3 or 4 I have seen with 12 points; but probably they are formed by two being laid -· · - accurately on each other with the points between one another (Scoresby, 1809 entry for April 29th).

> …Some particles of crystallized snow fell. I found 5 or 6 new kinds all but one very small, seldom exceeding 1/20th of an inch in diameter: the most common of these forms of chrystallized [sic] snow, as likewise the largest seen, is that with 6 points radiating from the centre, having numerous -· · - collateral parallel ramifications in the same plane: this modification is sometimes above ¼ of an inch in diameter. Wind ENE. Therm. 11° of 12. Bar 29.68 Inches. Water freezes now with bay Ice (Scoresby, 1809 entry for May 1st).

In the logbook kept on the subsequent voyage of 1810, Scoresby preceded the record of his ninth voyage to the whale fishery with a section he has called “Observations on the Barometer, on Meteorology, and on Snow Crystals, together with a Description of The Whale, &c.” Among these pages, are five associated with snow crystals (see Appendices 2-4) that contain information based upon the 1809 data he collected and recorded in entries similar to and including those presented above. The first of these five pages, "No. §**A.** Crystallized Snow", is a description of Scoresby's first system of snow crystal classification. This is followed by "§**B.**", a page of 30 snow crystal drawings and accompanying interpretive "Notes & References" that include meteorological data and date observed. "§**C.**" features a two-part table to which Scoresby has given the title, ""A table showing in a compact manner the state of the Barometer, Wind &c. when each of the lamina of crystallized snow was seen 1809". The upper part is associated with the 30 drawings on page §**B.**, and the lower section is linked to drawings of 17 snow crystals included on page "§**D.**" under the heading "Microscopic appearances of Crystallized Snow. Notes and References". This 5-page section of the logbook ends with a comprehensive "table showing the kinds of Snow and hail which fell during different states of the Atmosphere in Greenland 1809" (Scoresby, 1810). These materials, along with Scoresby's meteorological observations made during the 1807, 1808, and 1809 voyages were laid before the Wernerian Society ("a young but thriving scientific society") by its president, Robert Jameson, on the 13th of January, 1810, in Edinburgh (Scoresby-Jackson,1861, p. 74).

Scoresby's interest in snow crystals continued beyond 1810. In his two volume set, "An Account of the Arctic Regions with a History and Description of the Northern Whale-fishery", he includes representations of ninety-six snow crystals, at 30X to 400X magnification (1820, Vol. II, plates viii-xi), as well as a table of the atmospheric conditions when each of the crystals was observed microscopically (1820, Vol. 1, p. 433). In Volume I, he presents an updated classification system. As in the 1810 logbook, there are "five general kinds or genera", but four of the original five have been given new descriptive labels. These are: "1. Lamellar. 2. A lamellar or spherical nucleus, with spinous ramifications in different planes. 3. Finespiculae or six-sided prisms. 4. Hexagonal pyramids. 5. Spiculae having one or both extremities affixed to the centre of a lamellar crystal" (1820, Volume 1, p. 427). The lamellar crystals have been further subdivided into four "distinct species", namely: stelliform; regular hexagon; aggregations of hexagons; and combinations of hexagons, with radii or spines, and projecting angles (1820, Vol. 1, pp. 427-428). Crystals making up the second genus were thought to occur as one of two species determined by the lamellar or spherical shape of the nucleus (1820, Vol. 1, p. 429). Scoresby, where possible, attempted to provide the temperature(s) where each genus and species was most likely to be observed. For example, Genus 5 fell on two occasions, once when the temperature was 22° [F] and again when the temperature was 20° [F]; Genus 2, Lamellar nucleus fell most frequently at a temperature of 20° [F] or 25° [F]; and Genus 1, Stelliform occurred "in the greatest profusion" when the temperature approached the freezing point [32° F] (1820, Vol.1, pp. 431, 429, 427, respectively).

Given the use of the fabricated scientist's notebook in the research of Palinscar and colleagues, it's not difficult to envision how to best utilize the historical materials described here. Scoresby's personal study of snow crystals could be incorporated as the second-hand investigation in an inquiry-based approach to learning about weather, particularly snow crystals and their morphology, classification, and the temperatures and humidity levels under which specific types "grow". Once learners have drawings and/or digital images of the detailed shape and structure of the snow crystals they had observed over a period of time in a variety of weather conditions, it would be possible to present and discuss Scoresby's tables and illustrations and to begin to look for the patterns he hoped to identify both for classification and for the condition of the air vs. classification type (Scoresby's genus and species). Time permitting; it would be interesting and worthwhile to familiarize students with the snow crystal studies of others. This could include Robert Hooke's *Micrographia* drawings of snow crystals that fell onto a piece of black cloth or black hat (1665), the photographs of snow crystals taken by Wilson Bentley as well as his method for taking pictures and the classification scheme invented for their description (Bentley & Humphreys, 1931, reprint 1962), the classification key (field guide) developed by Edward LaChapelle (1969), Ukichiro Nakaya's exploration of the formation of synthetic snow crystals and the invaluable contribution of his research to the questions Scoresby was attempting to answer (1954), and, most recently, the photo-microscope work of Kenneth Libbrecht and Patricia Rasmussen (2003) and the electron micrographs of Eric Erbe and William Wergin (Amato, 2004). My opinion is that such modifications to the model of teaching described in several reports by Palinscar, Magnusson, and Ford could bring children as close as it may be possible to the ongoing dialogue between "the book of nature" and "the book of science" that Stinner (2001) describes as the style of reasoning used by scientists in their conceptual struggles to understand the physical world. Such a curriculum is being developed to determine if such a view is justifiable.

Notes

[i] It was argued that (a) observations are expressed in the language of a particular theory, are checked for acceptability by recourse to theory, and, as a consequence, are influenced by the theoretical perspective of the observer (it's "not possible to observe things that you don't expect, don't know how to look for and are not conceptually prepared for" - Hodson, 1998, p. 11); (b) the "objects of science" (*e.g.* concepts, the relationships posited as existing between formally specified entities, and theoretical explanations) do not emerge in a non-problematic way from observations but are inventions that have been imposed on phenomena in attempts to interpret and explain them, often as results of considerable intellectual struggles" (Driver, *et. al.*, 1994, p. 6); (c) scientific theorizing is prior to practice – McGuire, 1992, p. 146 ("experimentation is not the initiator of speculation (as the inductivist discovery methods imply), but the retrospective and rigorous testing of the adequacy of a particular theoretical proposition for explanation and prediction" - Hodson, 1988, p. 29); (d) explanatory theories are tentative ("our 'current best shot' at explaining 'how things' are in the physical world"), but theory rejection is a rare event in science - Hodson, 1998, p. 18); (e) theories cannot be logically assessed through their observational consequences ("scientific theories are empirically under-determined… Consistency with observable facts… simply means a theory may be true" – Hodson, 1998, p. 15), consequently, the distinction between the context of discovery (how objects are contructed out of experience) and the context of justification (how statements about objects are evaluated) is misguided – both count (Duschl, 1990; McGuire, 1992); (f) science is a communal activity and scientific knowledge is socially negotiated within the community of scientists ("the ideas of a particular scientist only become accepted as scientific knowledge when they achieve consensus with the community… many of the sociological, psychological, political, and economic issues that influence individuals could, and sometimes will, influence the decisions that the community makes" – Hodson, 1998, p. 16); (g) transition from one theory to another is not cumulative ("logical and empirical content are not entirely preserved when a theory is replaced by a newer theory" - McGuire, 1992, p. 145); (h) scientific change is complex and involves the destruction and dismantling of explanations and the replacement, substitution, and abandonment of knowledge claims (Duschl, 1990, p. 20); and (i) science progresses between periods of scientific revolution "as each new theory is developed and extended to new areas of applications" (Kourany, 1987, p. 231).

[ii] These domains are knowledge of philosophical and historical aims, goals, and purposes of education, knowledge of educational contexts, knowledge of learners, knowledge of general pedagogy, knowledge of curricula, knowledge of subject matter, and pedagogical content knowledge – the ability to transform subject matter into forms that are accessible to learners (Shulman, 1987; Wilson, Shulman, and Richert, 1987).

[iii] The passage read to the students had the heading, "Light and Optics" and is included here as an example of the genre. "Everything that we see fits into one of two groups. I one group are objects that give off light. They are called **luminous** objects. Light bulbs, the sun, flashlights are examples of luminous objects. The other group of objects do not give off light. We can see them only because light from luminous objects bounces off then and travels to our eyes. These objects are called **non-luminous** objects (Palinscar & Magnusson, 2001, p. 163).

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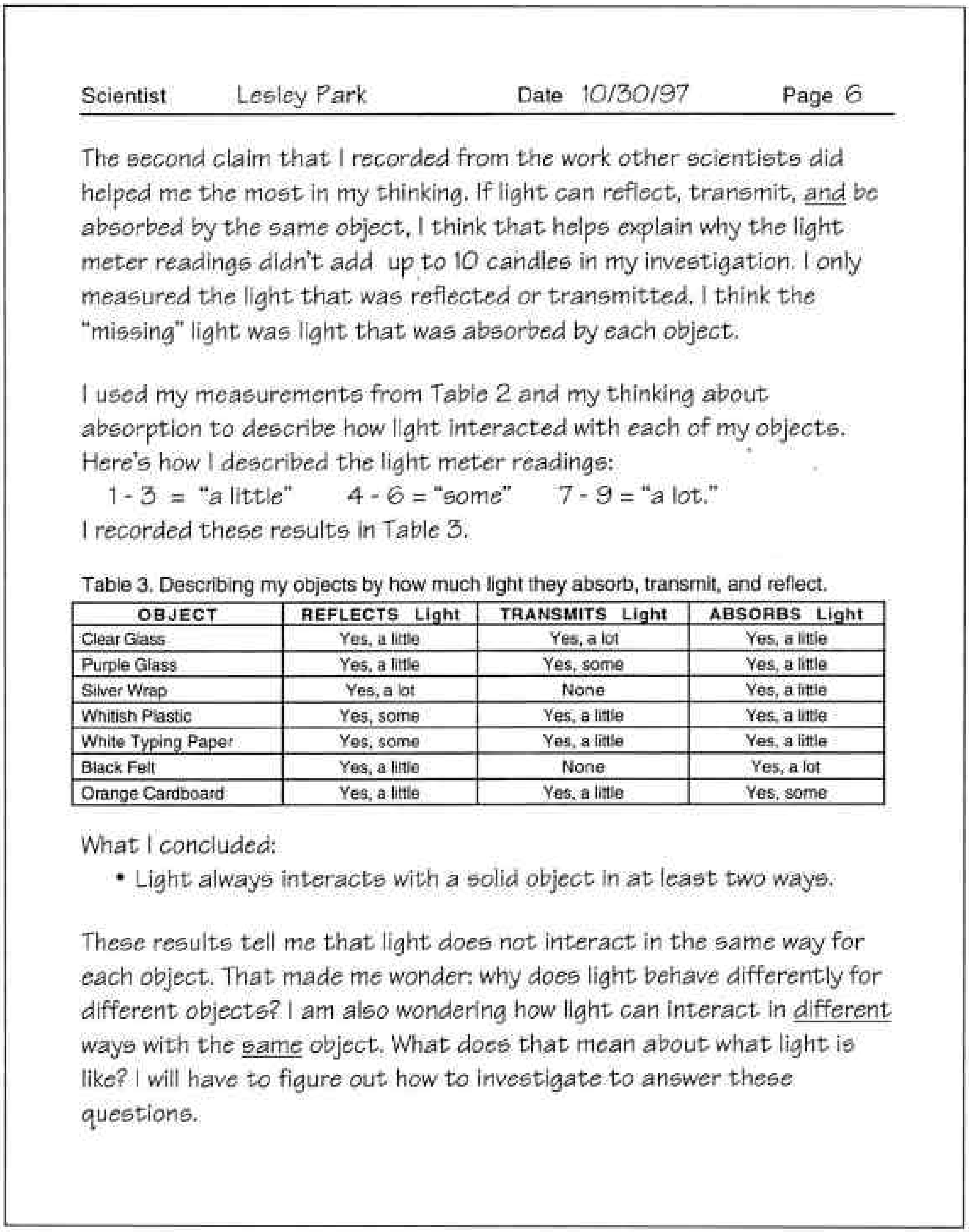
Appendix



Scientist Lesley Park Date 10/30/97 Page 6

The second claim that I recorded from the work other scientists did helped me the most in my thinking. If light can reflect, transmit, and be absorbed by the same object, I think that helps explain why the light meter readings didn't add up to 10 candles in my investigation. I only measured the light that was reflected or transmitted. I think the "missing" light was light that was absorbed by each object.

I used my measurements from Table 2 and my thinking about absorption to describe how light interacted with each of my objects. Here's how I described the light meter readings:

1 - 3 = "a little" 4 - 6 = "some" 7 - 9 = "a lot."

I recorded these results in Table 3.

Table 3. Describing my objects by how much light they absorb, transmit, and reflect.

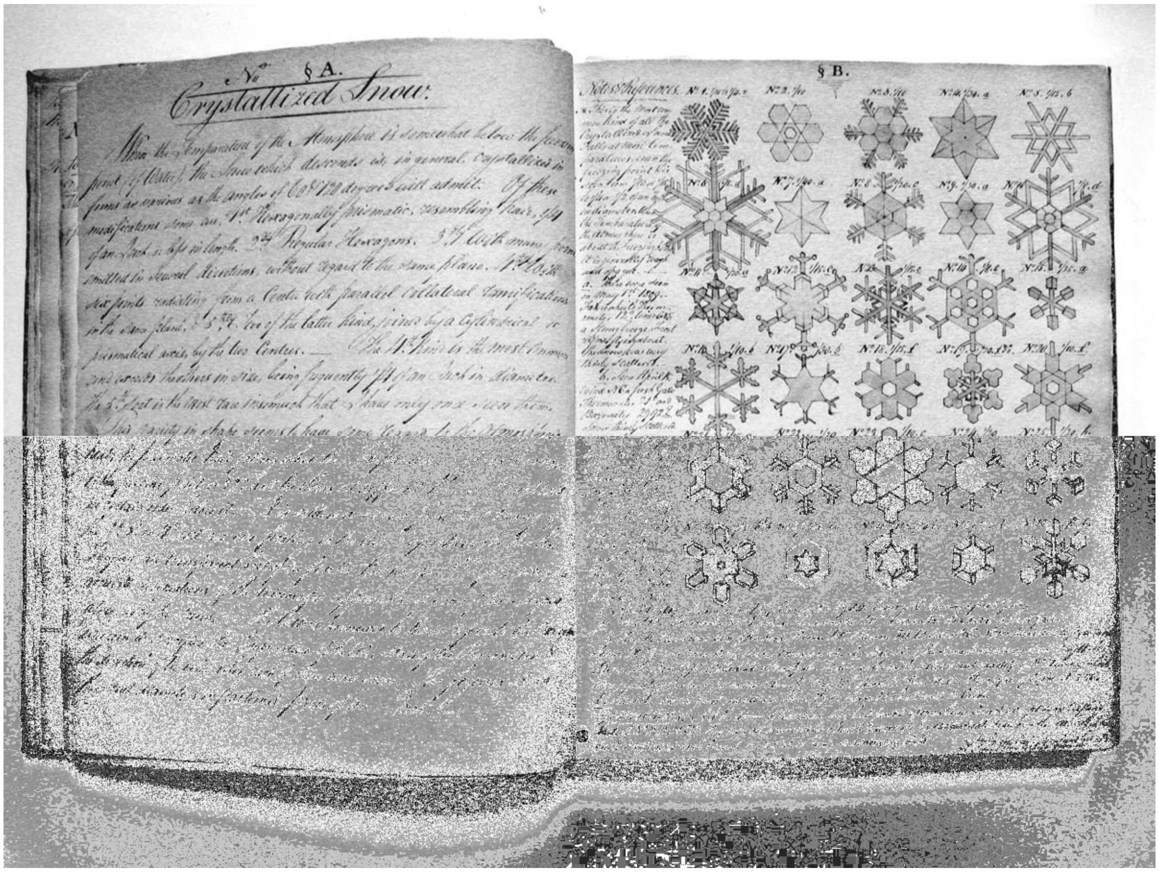
OBJECT	REFLECTS Light	TRANSMITS Light	ABSORBS Light
Clear Glass	Yes, a little	Yes, a lot	Yes, a little
Purple Glass	Yes, a little	Yes, some	Yes, a little
Silver Wrap	Yes, a lot	None	Yes, a little
Whitish Plastic	Yes, some	Yes, a little	Yes, a little
White Typing Paper	Yes, some	Yes, a little	Yes, a little
Black Felt	Yes, a little	None	Yes, a lot
Orange Cardboard	Yes, a little	Yes, a little	Yes, some

What I concluded:

- Light always interacts with a solid object in at least two ways.

These results tell me that light does not interact in the same way for each object. That made me wonder: why does light behave differently for different objects? I am also wondering how light can interact in different ways with the same object. What does that mean about what light is like? I will have to figure out how to investigate to answer these questions.

(Palinscar and Magnusson, 2001, p. 193)

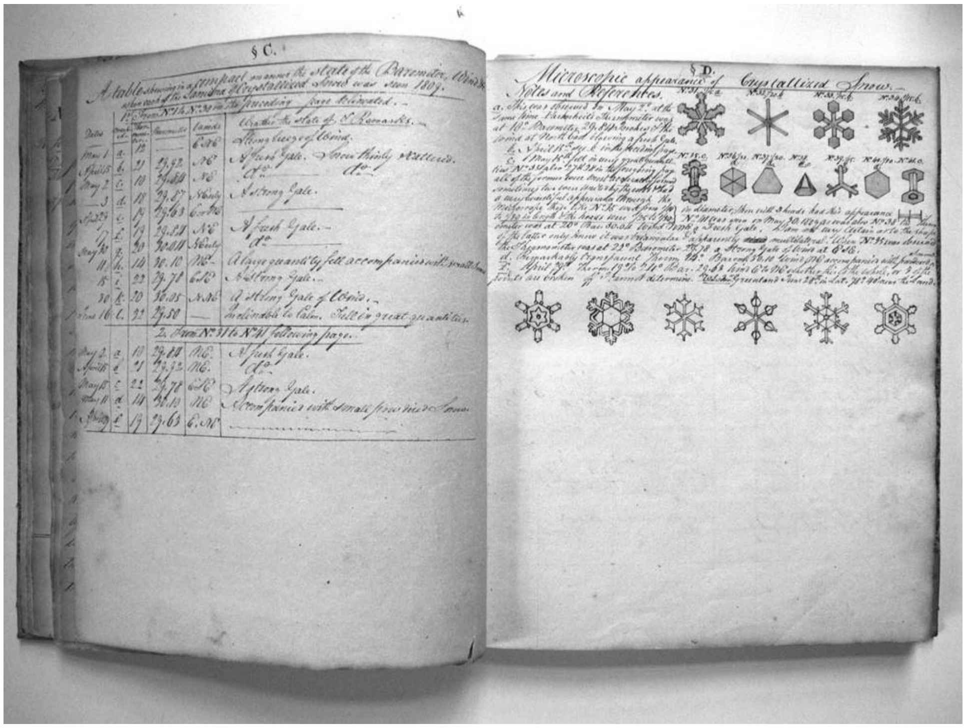


Transcriptions

§A
Crystallized Snow

When the temperature of the atmosphere is somewhat below the freezing point (of water), the Snow which descends is, in general, crystallized in forms as various as the angles of 60 & 120 degrees will admit. Of these modifications some are, 1st. Hexagonally prismatic, resembling hair, 1/10 of an inch, or less in length. 2dly. Regular Hexagons. 3dly. With many points emitted in several directions, without regard to the same plane. 4thly. With six points radiating from a Centre with parallel collateral ramifications in the same plane. & 5thly. Two of the latter kind, joined by a cylindrical or prismatical axis, by the two centres. The 4th kind is the most common and exceeds the others in size, being frequently ¼ of an inch in diameter. The 5th sort is the most rare insomuch that I have only once seen them. This variety of shape seems to have some regard to the atmospheric heat, the prismatic hail falling when the Temperature approaches near to the freezing point or 32°, and the others at different degrees, though with no certain order below it. Tis seldom a severe frost but many of the 2d, 3d, or 4th sort are seen floating in the air & sparkling in the Sun. They are all transparent but of no finite thickness. The following are accurate delineations of the microscopic appearance of some of the shapes assumed by the Snow. The letters annexed to them refer to the margin wherein is specified the Temperature of the Air; State of the Barometer, & the direction of the wind when each of them was seen. The figures show their actual diameters in fractional parts of an Inch (Scoresby, 1810).

§B
Notes & References



* [asterisk refers to snow crystal No. 1] This is the most common kind of all the Crystallized Snow. Falls at most temperatures, even the freezing point & is seen from $^{1}/_{10}$ or $^{1}/_{15}$ to ¼ or ½ of an inch in diameter. When the Temperature of the atmosphere is about the freezing point it is generally rough and opaque. [Snow crystals are numbered from 1 (upper left) to 30 (lower right).]

a. These were seen on May 1st 1809 ~Fahrenheit thermometer 12°. Wind ENE a strong breeze. Frost rhyme flying about. The snow was very thinly scattered.

b. Seen April 15. Wind NE a fresh gale Thermometer 21° and Barometer 29.32 In. Snow thinly scattered.

c. Seen May 2. Wind NE. a fresh gale Thermometer 10° Barometer 29.84. Only a little fell.

d. May 3d. 1809. Therm. 18°, Bar. 29.87[.[Wind NEerly a strong gale.

e. Seen April 29. Therm. 19° to 24°. Barometer 29.63 Wind E or NE.

f. April 17, 1809. Thermometer 19°. Barometer 29.81 I. Wind NE blowing a fresh gale.

g. May 30. Barometer 30.04 Inches. Thermometer 20°. Wind NE to NNE a fresh gale.

h. May 11. Much was seen of this kind. Therm. 14°, Barom 30,10[.] Wind NE. Accompanied with powdered snow. No. 29 was remarkably clear & transparent. *i.* May 15. Of the same kind as was seen May 11. *j*. Therm. 22°. Bar. 29.78. Wind EN strong gale. This is as intermixed with a great quantity of N^{o}. 21, two of which were joined together by a prismatic axis. *k*. May 30th. Therm. 20° Bar. 30.05. Strong gale of wind at NNE. *l*. June 16. Fell in great quantities. Bar. 29.50 Therm. 32°. Inclinable to Calm.

General Notes: All the above delineations may be depended upon as being correct

Parts of N^{o}. 11, 12, 20 & 25. They were all examined by a double microscope & a sub[?]eple drawn on the spot which was quite sufficient each branch or radiation being so accurately alike.

Wm. Scoresby, Jun^{r}. Greenland Sea. Lat. 29° [?]

Time 17[?] am fishing grounds

§C

A table showing in a compact manner the stare of the Barometer, Wind &c When each of the lamina of Crystallized Snow was seen 1809.

	1st From N^{o}. 1 to N^{o}. 30 in the preceding page delineated.				
Dates	Marked	Ther-Mome-ter	Barometer	Winds	Weather, the state of, & Remarks
May 1	a.	12	-	ENE	Strong breeze of wind.
April 15	b.	21	29.92	NE	A fresh Gale. Snow thinly scattered.
May 2	c.	10	29.84	NE	d[itto] d[itto]
- 3	d.	18	29.87	NEerly	A strong gale
April 29	e.	19	29.63	E or NE	----------------------
17	f.	19	29.84		
May 30	g.	20	30.04	NEerly	d[itto] --------------------
11	h.	14	30.10	NE	A large quantity fell accompanied with small snow
15	i.	22	29.78	ESE	A strong Gale.
30	k.	20	30.05	NNE	A strong Gale of
June 16	l.	32	29.50	-	Inclinable to Calm. Fell in great quantities.
		2. From N^{o}. 31 to N^{o}. 41 following page.			
May 2	a	10	29.84	NE	A fresh Gale.
April 15	b	21	29.92	NE	d[itto]
May 15	c	22	29.78	ESE	A strong Gale.
May 11	d	14	30.10	NE	Accompanied with small powdered Snow.
April 29	f	19	29.63	E.NE	-----------------------------

§D

Microscopic appearance of Crystallized Snow Notes and References

[Snow crystals in upper left are numbered from]

a. This was observed on May 2^{d}. at the same time Farhrenheit's [sic] Thermometer was at 10° - Barometer 29.84 Inches & the wind at North East blowing a fresh gale.

b. April 15th see b in the preceding page.
c. May 15th fell in very great quantities Nº. 35 also 27 & 28 in the foregoing page all of the former were most accurately formed sometimes two were united by their ends and had a very beautiful appearance through the microscope these like Nº. 15 were from $^1/_{10}$ to $^1/_{30}$ in length & the heads were $^1/_{25}$ to $^1/_{30}$ in. in diameter; those with three heads had this appearance [see illustration]. Nº. 41 was seen on May 39, 1809 as was also Nº. 38 the thermometer was at 20° Bar. 20.04 Wind NNE a Fresh Gale. I am not very certain as to the shape of the later only know it was triangular & apparently multilateral. When Nº. 35 was observed the Thermometer was at 22° Barometer 29.78 a strong Gale of wind at ESE.
d. Remarkably transparent Therm. 14°. Barom. 30.10 wind NE accompanied with powdered Snow.
e. April 29th Therm. 19° to 24° Bar. 29.63 Wind E to NE whether this is the whole, or 3 of the points are broken off I cannot determine. WS. Junr. Greenland June 28th. In Lat. 78°40' near the Land.

A table showing the kinds of Snow or Hail which fell during different states of the Atmosphere in Greenland 1809.

Dates	Therm.	Barom.	Winds	Weather &c.	Kinds of Snow or Frost which fell.
May 16 [&] 17	30°	29.56	SE	A fresh breeze.	Prismatic Hair like Snow. 1st kind **A**.*
May 18	31°	29.65	Wly	Moderate breeze	d[itt]o ------------fell in thick flakes.
Apl. 15	21°	29.92	NE.erly	Fresh Gale	Flat crystallized Snow.
17	19°	20.84	NE to N	Fresh breeze.	d[itt]o ----------------------
23	27°	30.46	W	Fresh breeze.	Prismatic Hail $^1/_6$ to $^1/_8$ of an Inch long.
25	31	29.77	SSW	Moderate breeze	Uncrystallized Snow or opaque Hail.
26	32°	29.28	SW	d[itt]o Gale.	
27	30	29.36	WSW	Fresh breeze.	
28	28°	29.60	W.erly	Little wind.	
29	19°	29.63	NE	[?] breeze	Two laminae joined by an axle. 5th. Kind **A**.
30	7°	29.82	To N	Fresh Gales.	Frost rime. Like powdered Snow.
May 1	11° 12°	29.68	ENE	Fresh Gale.	Fine small, flat crystallized Snow.
5	29°	29.72	WNW	Moderate breeze.	Roughly cryst. Opaque like 4th kind **A**.
7	29°	29.60	NW	Fresh breeze.	d[itt]o ------------------------- d[itt]o---
24	21°	29.95	N&E	Moderate breeze.	Roughly cry. Like No. 1. **B** of a large size.
25	17°	29.97	North	Strong Gale.	d[itt]o ----------- in small quantities.
29	20°	30.04	NNE	Fresh Gale.	Flat laminae joined by an axis like 5th. **A** intermixed with Nos. 36, 37, & 40 of **D**
31	23°	30.08	NE	Strong Gales.	
June 11	30°	30.00	SW	Moderate breeze	A few showers of Hair like Snow 1st kind **A**
17	32°	29.62	SW	d[itt]o	d[itt]o --------------- in large flakes
19	27°	29.90	SW	Strong breeze	Prismatic hail like No. 1 A. Tough & opaque in large quantities [?] large flakes of [?] No. 4 **A**. with [?] like 38 in **D**.
26	31° 32°	29.78	SSW	d[itt]o	
July 1	28°	29.75	W.erly	Light breeze	Coarse opaque hair like Hail..
5	32°	30.06	S.erly	d[itt]o	d[itt]o --------------------------------
8	33°	29.94	SW.erly	Fresh Gales	Fine Hail or Snow of No. 1 **A**.
11	36°	29.50	NW	Strong Gales	d[itt]o--------------------& fell in huge flakes