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ABSTRACT

This paper describes the Primary Science Project in Norway whose goals were to describe the primary (grades 1-6) science classroom and to make recommendations on improvements for primary science teaching. The purpose of this study was to study the classroom climate, specifically focusing on the social interactions between teachers and students. The lessons were coded by observers and videotaped to give multiple sources of data. Conclusions from the classroom observations were that boys at each class level receive more attention than girls; a small number of students answer the questions in a class discussion; when given the choice, students prefer to work in single-sex groups; girls appear to be more bothered by a noisy, unstructured class than are boys; boys begin activities more quickly than girls; boys are more likely to make up additional experiments when they have finished assignments; and girls are more likely than boys to finish written reports. Samples of curriculum written for this research are provided. Teaching strategies to improve this situation are suggested. (CW)

The Primary Science Project in Norway: Action Research and Curriculum Development

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This is a paper about a Primary Science Project in Norway which began in 1986. The original goals of the project were to describe the primary science classroom and to make recommendations on improvements for primary science teaching. Once out in the schools, the goals of the project quickly changed. What we thought we would find was quite different from what we actually found! What follows is a description of the journey we have taken in the past three years, using the school environment as our guide.

But before we embark on the journey, it is perhaps best to describe the Norwegian school system so you can begin to understand what the primary school environment is like in Norway.

Education in Norway - A Unique Model

The underlying goals for education in Norway are to provide instruction and socialization for the individual. Though instruction clearly dominates, schools have been given more and more of the social tasks families and communities have assumed in the past.

There are four clearly defined levels of instruction in Norwegian schools: Primary, Lower Secondary, Upper Secondary and Tertiary (Fig. 1).

Primary and Lower Secondary Education

Children begin their nine year compulsory education at the age of seven. Before this time roughly 20% have attended nurseries where the instructional emphasis is on socialization through activities.

Compulsory school is divided into primary schools (grades 1-6) and lower secondary schools (grades 7-9).

Norway has a national curriculum which directs instruction in all schools. This is perhaps not so surprising with a population of only 4.2 million people. The problems involved with the implementation of a national curriculum arise due to the extensive geography of the country. Small rural schools must be given the same opportunities as large urban schools.

The curriculum materials developed in Norway follow the subjects of the national curriculum. Books must be approved by the Ministry of Education for content as well as for adherence to gender equality regulations. Teachers direct curriculum through choice of textbooks and interpretation of when and how much content is to be taught. As in most other countries, teachers at this level of instruction teach many different subjects and are textbook dependent in practice.

Pupils remain together in the same class for the first six years of their education. One teacher will often follow the same class of pupils from grades 1-6 and then return to grade 1 to begin the cycle again. It is forbidden to group pupils in grades 1-9 according to ability level. The Norwegian school system places a strong emphasis on the socialization of the individual child and thus the need for a safe and familiar learning environment. Children with special physical and/or mental needs are integrated into regular classrooms whenever possible.

Upper Secondary Education

The upper secondary level of instruction is not compulsory. It is divided into an academic direction and a vocational direction. The academic direction is followed by 40% of all pupils and gives access to tertiary level instruction.

The first year of the academic direction has a common curriculum for all students, including science, mathematics, social science and language. In the last two years of study students choose a concentration in either the sciences, social sciences or languages. There is currently a trend in the academic direction to do away with the three areas of concentration, thus allowing pupils more choice across the curriculum. Science educators are not convinced that this decision is wise since the latest statistics indicate a move away from a concentration in the sciences in favor of languages.

Teacher Education

Teachers enter the teaching profession from one of two pathways.

1. Teacher training colleges provide a 3-year tertiary education, preparing teachers for grades 1-9. The emphasis at these colleges is pedagogy. As of today, the only required courses are pedagogy, religion and Norwegian language. Students are free to choose areas of concentration within the curriculum. A degree from this institution qualifies teachers to teach all subjects from grades 1-9.

   There is a strong movement to structure the courses taken by students in these institutions. It is of course our hope that science and mathematics will be added to the list of required courses.

2. University studies with the addition of a half-year practical pedagogical training qualifies teachers for the secondary school (grades 7-12) but only in the subject areas where they have competency. University studies may be a basic degree (3.5 years) or an advanced degree (5 years).

The teacher education system is currently under review and hopefully reorganization. Teachers coming from teacher education institutions are in need of additional content courses. On the other hand, teachers coming from a university background are in need of additional pedagogy courses.

Science in the Educational System

Science education in Norwegian schools is heavily influenced by trends in England and America. Our latest national plan for science emphasizes the importance of methodology in teaching science; that children be active learners. There is also a strong tendency to relate science topics to every day situations, realizing that science is a subject area necessary for all citizens. And of course, the latest developments in science are the "green" topics covering across the curriculum environmental topics.

Primary Science

In grades 1-6 science is not taught as a separate subject but as a part of an integrated subject called "orientering"."Orientering" contains the four subjects; social studies, history, geography and science. This is an example of subject integration at its best when one thinks of all of the possibilities of thematic integration. The theory behind the idea was good but in practice does not work.

Orientering books are an accumulation of separate chapters that skip from one subject to the next without connection. The result for science is that teachers hop over the difficult science chapters and go on to geography or history. In the end they can safely say that they have taught orientering without spending much time at all on science topics. We have **successfully integrated science out of the primary curriculum!**

Primary teachers have little to absolutely no science education beyond their first year of upper secondary school. Science is not a required course in our teacher training colleges, and therefore not chosen by most teacher education students. In addition, most of our primary teachers are women who have never cared for learning or teaching science. It should be no wonder that little primary science is taught in Norwegian schools when we start out with three strikes against us.

Lower Secondary Science

Science is a required course in all three years of lower secondary education. It is an integrated course including Physics, Biology and Chemistry; taught for 3 hours per week out of a total of 30 hours.

Science teachers at this level come from both teacher training colleges and from universities; the one group concentrating on pedagogy, the other on subject. Very few teachers from either of the institutions have studied all of the three sciences at the tertiary level.

Pupils make decisions about their academic careers at the end of grade 9 when they choose to enter an academic direction or a vocational direction. If we turn them off to science at this age, we have little to no chance of ever getting them back again. This is a most important issue in Norway for recruitment of girls to science; a seemingly endless uphill battle.

Upper Secondary Science

Students who have chosen the academic direction take a common science course in grade 10. Like courses in the lower secondary, this is an integrated course including Physics, Chemistry and Biology. The course is taught for 5 hours per week as a combination of lab and lecture.

Upper secondary science teachers have completed a university degree in at least one of the sciences. Most are qualified to teach at least two science subjects and mathematics as well. Few have the formal qualifications needed to teach the integrated science course taught in grade 10.

We see the individual science areas; Physics, Chemistry and Biology, appearing in the curriculum for grades 11-12. Students concentrating in the sciences have a variety of opportunities at the end of secondary schooling. Many will choose to further their science studies at the university level. Others will choose engineering or medicine.

The Primary Science Project

When the Primary Science Project began in 1986, there was a good deal of statistical information available on the state of primary science. Norway participated in the Second International Science Study (Sjøberg, 1986) and had been involved in a large project involving girls and physics (Lie and Sjøberg, 1984)

We knew that science was not considered a priority in the primary curriculum. We knew that teachers had little to no formal science education. We knew that science had been integrated into a subject called "orientering" but knew little about how this new subject was being taught. We knew that schools spent little to no money on science equipment.

The Second International Science Study also gave us information on children's attitudes to science as well as their experiences within science areas. From this information we knew that grade four pupils generally had a positive attitude towards science. What was alarming was the general decline in positive attitudes between grade 4 and grade 9 pupils. This was especially apparent with girls!

Gender differences also became apparent in test scores with boys generally performing better than girls. It is safe to say that we could have wished for better scores overall in content areas for all students at grade 4.

Data on experience with science objects and/or topics outside the classroom gave very interesting information on the differences between what boys and girls do with informal science. Boys had much more experience and interest with topics we could characterize as Physics (model building, using tools, repairing things, changing batteries, etc.). Girls had experience and interest in topics characterized as Biology (plants, human body, animals, food, etc.).

After a careful assessment of what we thought we knew about primary science, it became apparent to us that there were many pieces of information of a qualitative nature that were lacking. We knew little about actual classroom teaching situations in primary science. We had important questions that needed to be answered concerning the methods used to teach science topics, the amount of content knowledge required and the combinations of methods and content found. We were also most interested in studying gender issues related to the teaching of science topics.

We came to the project with a constructivist perspective on what we considered to be good science teaching (Driver, 1983, Driver, 1989). Children are responsible for what they learn, they come to the science classroom with notions of the world around them, they need to be challenged to explore their own alternative conceptions before being willing to accept new and/or different concepts. We knew little about how a conceptual change model of science teaching would function in primary schools.

What a great disappointment it was for us when we finally began working in schools to discover that there was literally no science teaching to observe. The closest we came to a science lesson was a reading assignment in a textbook. This is when the project became an action research project. We recognized a problem, wanted to change it and then wanted to study the effects of the change.

Three factors pointed to the sorry state of science in our schools:

1. Science had been integrated away from the curriculum.

2. The majority of primary teachers are women who do not enjoy teaching science topics.

3. The majority of primary teachers have little to no formal science background.

Our task was now to try and improve this situation, both for children and for teachers. The immediate answer was to begin writing curriculum materials that would activate children as well as teachers in science.

Curriculum development

Science is one of the few subjects in the curriculum that allows kids to do what kids can do best; ask questions and use their creativity to wonder about the world. Primary science has the potential to be one of the most liked subjects in the curriculum if only we give kids the chance to be inquisitive and active. Science activities actually encourage kids to work together, to make some noise, to create things, to wonder about things.

With these thoughts in mind we set out to create science activities that would and could be used by our primary teachers. We worked together with 12 teachers from 2 schools, all of which taught in grades 4-6. Teachers have worked together with us in the curriculum development process. They have used the materials in their classes while we have observed them in action. Their comments together with our observations and interviews have served as the basis for curriculum development.

The Project Design, including background theory, development and evaluation of the materials is presented in figure 2.

In a two year period we have developed units in four areas: Magnets, Mystery powders, Sound and Light. In each of the units we have tried to incorporate new methods for teaching science, always trying to improve on our model of curriculum development.

In our first unit on Magnets we were concerned with developing science activities that would involve all pupils actively. We concentrated on methods for opening a unit that could grab the attention of all pupils, and not just those who had experimented with magnets before. We learned the importance of using activities to give all pupils a common ground before going further in their discoveries.

In the second unit on Mystery Powders we were looking at how children work in groups. The activities and the reporting were all group efforts in this unit. In addition, we looked at the role of the teacher while group activities are going on. We learned how important it is for teachers to have methods of interrupting group work in order to guide the lesson and keep the groups going in the right direction. Teachers successful in managing group work were also teachers who had a means of showing pupils that they were in control of the class.

The unit on Sound was used to experiment with the use of descriptive writing in the science lesson. This unit will be reported on extensively in the latter part of the paper.

The fourth unit on Light concentrated on uncovering children's alternative conceptions about light.

Model for curriculum materials

After much trial and error, we have ended up with a working model for how curriculum materials should look. We have combined our knowledge of the primary classroom together with research on conceptual change models for science curriculum development (Driver, 1989) The materials consist of two parts: a student workbook and a teacher's guide.

1. The student workbook includes the activities for the children and a text book. The activities are meant to be carried out in the classroom under the direction of the teacher. The text book may be read in the classroom or used for homework reading. Many of the explanations for the activities are found in the textbooks, as well as information which places the science topic into a broader societal context.

2. A teacher's guide includes all of the information in the student workbooks and detailed information on each activity. A description of the activity, examples of typical questions children are likely to ask and a bit of theory on the science topic are included for each activity.

It is perhaps of interest to describe the development of the teacher's guide. We began the project thinking that we would of course need to give teachers science information because they had so little in their backgrounds. We assumed that they were skilled in the use of methods and, in the beginning, wrote very little about this.

Once again, to our surprise, we discovered that when it comes to science, even the most skilled classroom teacher seemed to forget all of the good methods they had developed in other subject areas and they were left almost helpless in knowing where to begin. We now write teacher's guides with an integration of content and methods.

We have also experimented with the amount of content we were allowed to present to teachers. Our aim has always been to use the teacher's guide as a means of teaching teachers more science. If, however, we tried to present concepts that were difficult to understand, teachers were quick to tell us that they did not appreciate reading our explanations. Our teachers used their teacher's guides much more religiously than we had anticipated. They used the content explanations we had written "just for teachers" in their discussions with their pupils. For this reason we needed to revise our materials for teachers.

The pupil workbook is under constant revision after we observe how experiments function in the classroom. Classic experiments that are found in almost every primary science book often did not work in the way we had hoped. Then it is back to the drawing board to either revise the activity or think of a new one.

Sound

What follows is a description of what we have developed and learned while working with our unit on Sound. As mentioned before, we tried to experiment with new methods each time we began a new unit. We used the sound unit to experiment with writing in the science lesson. Our reasons for working with writing were twofold: we were interested in using writing to get at what kids already knew about sound and we wanted to see if writing encouraged greater participation and retention in the science lesson.

Our content objectives for the unit were simple. We wanted children to understand the concepts that sound comes from things that vibrate, that sound travels and that we use our ears to hear sounds.

The progression of activities found in the unit on Sound is as follows:

1. **What do we know about sound?**

   In this activity we ask children to write everything they can about the topic of sound. They later read what they have written to each other and write 2 questions on things they wonder about with sound. Every child is then given a rubber band to experiment with. The homework assignment is to make a musical instrument.

2. **Sound comes from things that vibrate.**

   In this activity children present instruments they have made at home. They work in groups to make a song or poem using their instruments to accompany them. After presentations to the class, each instrument is observed to determine what it is that actually makes the sound.

3. **Swinging Strings**

In this activity we provide a variety of ways to experiment with sounds created by plucking strings. We introduce the concept of pitch and loudness.

4. **Is there sound in outerspace?**

In this lesson we provide a number of activities that demonstrate how sound travels through different media. Children then make a telephone using yoghurt cups and string, followed by experiments using their telephones.

5. **Sound takes time**

This activity involves measuring the speed of sound out in the playground as well as finding an echo wall.

6. **How do we hear?**

We study our own ears in this activity, how sound waves travel from a source into our ears and eventually ending up in a message to our brain. The shape of ears is discussed with reference to animal ears.

7. **What do we use sound for?**

We use this activity to introduce sound as a part of our environment. The deaf alphabet is introduced.

At the end of the unit, pupils were once again asked to write about sound as they had done in the first exercise. And, one year later the same pupils were asked to write about sound once again.

Writing in the Science Curriculum - Before and After

The first writing assignment had the intention of learning about what children think about when they write about sound. The assignment was not given in the context of the science lesson and therefore reflects general thoughts about sound. In almost every case, from grade 4-6, children chose to write about types of sounds, using lots of adjectives to describe sounds. Scientific terms were not found in the majority of these essays, apart from isolated cases where sound waves were mentioned. If a scientific term was mentioned it was a boy who wrote the essay.

The information obtained from these first essays told us that children in this age group do have a concept of sound which is connected to sounds they hear. They have not chosen to write about what sound is as we might describe it in a scientific way.

The purpose of the writing assignment after completion of the science unit is to provide information on what was learned and retained by the children. After completion of the sound unit, the writing assignments have changed their character to reflect that which was presented in the science lesson. Pupils refer to at least one scientific word or concept in their essays.

The information obtained from the second writing essay was used to evaluate our curriculum materials. We were pleased that pupils had retained many of the simple concepts we hoped to demonstrate through the experiments and reading assignments. We were also able to pluck out incidences where children had formed alternative concepts about sound to the concepts we had presented. This information is very important in the curriculum evaluation and revision process. Did the "mis-information" come from the activities, from the teacher explanation or from the combination of the child's previous ideas about sound when combined with new information.

After one year, we were very pleased to see scientific terms and concepts about sound in the writing assignments. Our impressions when reading the essays are that concepts are directly related to experiments that the children remember doing. Many even describe the experiments they remember. The importance of activity based science can not be underestimated when we see how the activity is coupled to retention.

Kristine, Tone, Leif and Cecilie - Fourth graders write about Sound

The best way to demonstrate the changes in what children chose to write about, is to follow the progression of individual children. What follows are the essays of four fourth graders, all from the same class. Their teacher was petrified when we told her she would be teaching a unit on sound. She has no science background yet knew that sound had something to do with that awful word "Physics". The results of the writing assignments indicate that the curriculum materials allowed her to complete a unit on sound with positive results.

Kristine

What I know about sound:

Pre-instruction

It is everything we can hear
It is music
It is words and noise
Without sound the only way we could be understood is with
drawings and pictures.
Even the soft beating of a heart is sound
But if sounds are too loud our ears can be ruined.

Post-instruction

Air vibrates when sounds are made.
There is no sound where there is no air.
The ear drum and the ear bones must vibrate before we can hear sounds.
If we hear a very loud sound our ears can be ruined and then we can't hear.

One Year Later

There must be vibrating air before there can be sound. When air is made to vibrate, sound is made. The kind of sound depends on if the string is thick, thin, short, long, tight or loose.

Tone

What I know about Sound

Pre-instruction

Sound can be high or low, beautiful or ugly, jerky or flowing, soft, nice, boring, fast, slow or just right. Sound makes it possible for us to hear someone who makes a sound. We can put different sounds together, for example **S - O - U - N - D** and we know that it is sound. Sound can be scary of calming. It is a good thing that we have sound for example when someone falls through the ice and yells for help someone can rescue them because they have heard "help". We hear with out ears.

Post-instruction

Sound is something we hear with our ears. Sound goes through solid things like water air trees etc.
Our ears can't stand too much noise.
It isn't just our ears that are bothered but also our whole body.
We can insolate for sound.
Sound vibrates in the air
Sound can be a signal like when someone blows a whistle at a soccer game and the players know that means something when it sounds.

A sound can be low, high, weak or loud.
Thick rubber band = low tone
Thin rubber band = high sound

One Year Later

I know that music instruments are divided into four groups: Blowing instruments, string instruments and percussion instruments. String instruments are made in the same way as when you put a rubber band over a box. Air vibrates in the box and there is a loud sound. If you take a loose rubber band, the rubber band is low and if you take a tight rubber band the sound is high. The loudness of sound is measured in DB. Thunder is one of the loudest sounds. Breathing is one of the softest sounds. There is no sound in space. That is because there is no air there and then sounds can't vibrate. Sound can be harmful. You can ruin your hearing, you can be stressed. You can insolate your house with insolation and pillows rugs furniture, plants and covers etc. Sounds can be signals like whistling, alarm clocks, game whistles etc.

Leif

What I Know About Sound

Pre-instruction

Sound is really important for people and for other animals. There are a lot of different sounds. Sound can be weak or even very loud. There is something that is called SOUND waves. They float around in the air and then go right into our ears and then we are able to hear. SOUND waves are like ghosts, because they go right through thick walls, and no one can see them either.

Post-instruction

Sound is made from vibrations. Sound waves come from the vibrations. They go into our ears. There can be high and low tones. Sound waves and invisible. Thunder travels at a speed of 340 meters per second in the air. We can make many different kinds of sounds. For example, we have instruments that make sounds and all of the sounds are made from vibrations. Sound waves are just like ghosts. We can not see them and they can go through a wall. People also make sounds that mean something. Like tooting. We also make sounds when we talk to each other.

Cecilie

What I Know About Sound

Pre-Instruction

Sound can be both high and low tones.
People hear sounds. People hear some sounds and not other sounds. Sounds can be nice to hear or they can be awful to hear.

Post-Instruction

Sound is something we hear. It comes in sound waves through air. There are high tones and low tones. Loud sounds and soft sounds like whispering. Sound travels at 3400 m pr. sec. If you move something it vibrates and sound comes out.

One Year Later

Sound travels in sound waves through the air. You can't see sound waves in the air, only in water. If you drop a stone in the water you can see circles of waves around the stone you threw. The circles get bigger and bigger the longer out they are, and they get weaker and weaker. *These are sound waves from the stone.* Sound travels faster under water than in the air.

(Note the marked text which demonstrates a possible mis-conception due to the presentation of a model.)

Writing as Evaluation

If we consider the objectives we had for the unit on Sound, our writing assignments after one year would indicate that children had acquired more of the "scientific" concepts of sound than they had before the unit began. What is evident is that they remember activities in the unit and they associate concepts with the activity. An example of this would be the exercise using the rubber band and the box. Remembering the exercise allowed children to also remember that strings of different sizes and thicknesses gave different tones. Some even remembered that the air inside the box was vibrating.

From a methods viewpoint, we have explored the use of writing as a means of getting at what children know and think about a topic and as a means of evaluating what they have learned. We think that writing is a very powerful tool in the science classroom for many reasons. As an introductory activity writing involves all children and gives every child something to talk about in future lessons. It is no longer just the eager boys who have experience with the science topic who have something to say. Because they have written about the topic, all children now have something to contribute.

Writing as a diagnostic tool allows teachers to know what their pupils are thinking about, what they already know about and what they wonder about a topic. The pre-instruction writing assignment gives the teacher clues in how to proceed with the science unit based on the questions children ask and the things they already know about the topic. She can then tailor lesson plans to the needs of her pupils.

The post-instruction writing assignment is a diagnostic tool that allows for assessment of the unit. One can identify what children have learned, be it "correct" or "incorrect" when compared with school science. This information may then be used to re-visit the topic, perhaps using a different approach.

Writing is not the only way to activate children or to get at what children already know. It is, however, one method that may be used to accomplish this task.

Where do we go from here?

After three years of doing what we would call "Action Research" we are convinced that we are on the road to making improvements in Primary Science. We have accepted the slogan from America which says that "Less is More" by trimming our expectations for what should be taught at the Primary level of science instruction. We strongly believe that activities and experiences are the key to primary science if we are to interest both children and teachers. But we also state very firmly that activities and experiences need content knowledge as their driving force. Activity for the sake of activity is not enough.

We have looked closely at the role of the teacher in the science lesson, based on the situations we have in Norwegian schools. Their content knowledge in science is not as deep as a science educator would wish. Yet, we think we have found the key to the teacher's guide by also thinking of teachers as learners in the science lesson. Their role must also be that of a guide through the lesson, such that children always know who is in charge, where they have been and where they are going.

An historical view of where we have travelled in the past three years has shown us the importance of working within and not apart from the primary school environment. Teachers, students and administrators have played a very important role in shaping the curriculum materials and in accounting for the success of failure of a science program. The things we know today about teaching primary science are completely different from what we knew or thought we knew three years ago.

The project is now at a turning point where we will be moving away from curriculum development into case studies of teachers and schools where science is an active part of the curriculum. We are interested in using case studies to further identify factors that allow science to be taught. What makes a successful primary science teacher? How does the school environment influence the individual teacher? Why do some schools encourage science teaching and others actually discourage the teaching of science? What can we identify as appropriate pedagogic/content knowledge necessary for teaching primary science?

The underlying reasons for such research questions are to make visible the needs for improvements in science education at a national level. We do not believe that primary science is better off as an integrated subject in the current curriculum structure. We do believe that primary teachers should all be exposed to a formal course in science as a part of their teacher education.

We believe that science is an appropriate subject for the primary level of instruction and that children have much to gain by being exposed to science topics. It should be enough to say that children actually enjoy science and therefore we should do everything possible to ensure that they have this opportunity in our schools. If we can convince more teachers to also think of science as exciting and interesting, by providing them with the appropriate materials, education and support, then I believe that we are moving in the right direction for getting science back into our primary curriculum.

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