Claus Michelsen (editor)

Proceedings of the Fourth Nordic Network of Researchers in Science Communication Symposium

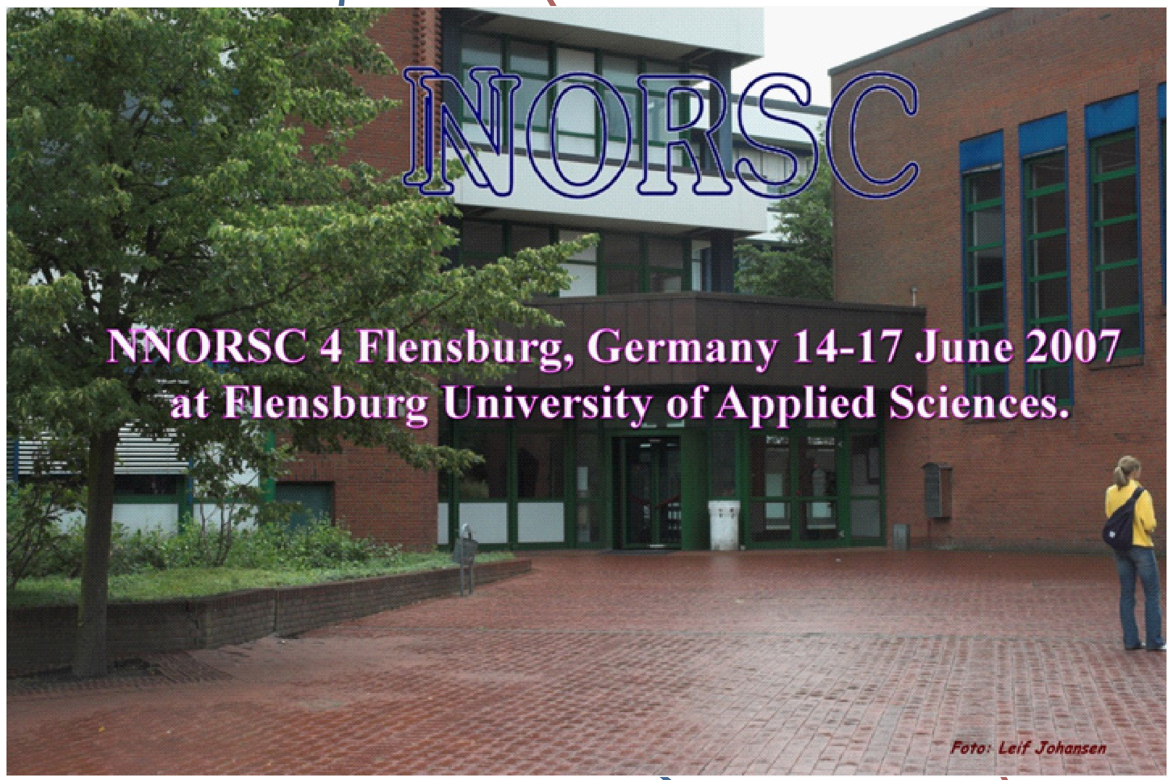

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Table of contents

Introduction

The Nordic Network of Researchers in Science Communication (NNORSC) group has been meeting regularly since 2004. NNORSC was founded on December 18th 2003 by its first four members Professor Lars Broman, Dalarna University, Pofessor Ann-Marie Pendrill Göteborg University, Professor Aadu Ott Göteborg University and Associated Professor Claus Michelsen, University of Southern Denmark. NNORSC is a network for senior researchers and graduate students involved in research on informal learning at science center surroundings and science-center-like contexts (i.e. learning with emphasis on interactive communication with artefacts and animals). Included is all work related to science centers and planetariums as well as interactive activities in different surroundings from museums to science festivals and theme parks (including amusement parks). The word "science" is used in its broadest meaning; the concept includes the natural sciences but also social science, technological science, etc. NNORSC is primarily open for researchers from the Nordic and the Baltic countries and from Schleswig-Holstein in northernmost Germany.

The first activity of NNORSC was the arrangement of the first yearly symposium at University of Southern Denmark in Odense in June 2004. 14 researchers from Denmark, Finland and Sweden attended the symposium. In addition 11 papers were presented in an interactive atmosphere. Proceedings from the symposium include the extended versions of some of the papers presented at Odense (Michelsen, 2005). The NNORSC 2 took place in Vantaa in Finland in June 2005 and was organized as a Nordic preconference to the ECSITE conference in Vantaa. 12 researchers from Denmark, Estonia, Finland and Sweden participated in the symposium. NNORSC 3 was held at Dalarna University in Borlänge, Sweden in June 2006 with 8 participants from Denmark, Finland and Sweden.

At the closing session of NNORSC 3 the city of Flenburg was chosen as the venue of NNORSC 4, The Fourth Nordic Network of Researchers in Science Communication Symposium. NNORSC 4 was held at the Flensburg University of Applied Sciences, July 14-17, 2007 and organized by Director Achim Englert, Phänomenta Flensburg, Professor Helmut Erdmann, Flensburg University of Applied Sciences, Ph.D.-student Anne Kahr-Højland, University of Southern Denmark, Dr. Michael Kiupel, Flensburg University and Associate Professor Claus Michelsen (chair), University of Southern Denmark.

NNORSC should be regarded as a manifestation of a long tradition of cooperation between the five Nordic countries. A cooperation which includes many issues such as culture, education and research and is based on a historic and cultural common denominator. The city of Flensburg is known as the city of two cultures – the German and the Danish culture. NNORSC 4 is arranged as a part of the project Lab to School, a research- and developmental project which is carried out in close cooperation between The Flensburg University of Applied Sciences and University of Southern Denmark. The project focuses on out-of-school activities in school laboratories at universities in the region of Southern Denmark and Schleswig, and the project is supported by a grant from the EU-program Intereg IIIa Sønderjylland/Scleswig. The project exemplifies the outstanding cooperation between universities and colleagues in the German-Danish border region. Flensburg and Schleswig-Holstein are also known as the gate to Nordic, and the choice of Flensburg as venue for NNORSC thus adds a new dimension to the term Nordic in NNORSC.

Much of the research concerning science centres has been completed science education researchers. Rennie & MacClafferty (1996) point at the necessity of getting science centres more involved in their own research. The NNORSC 4 symposium theme was *The necessity of increased cooperation between the researchers and science centres.* The theme was reflected by the composition of the participants who were researchers in science education, employees at science centres, and researchers employed at science centres. The symposium offered a unique opportunity to exchange knowledge and ideas across research in science education and science at science centres. For an emerging research field like science communication the sharing of experience and exchanging practice is of paramount importance. And as an effect the development of a Nordic profile for research in science communication is giving impulse – and by Nordic I mean the Nordic countries and the German-Danish border region.

NNORSC 4 attracted 38 participants from Canada, Denmark, Germany, Sweden and UK. The participants of NNORSC4 were invited to submit contributions to the present volume. It contains papers reviewed by the organizers of symposium. The volume mirrors main lines of research in science communication in the Northern part of Europe. The papers show that in the recent years new research groups has been created and new activities has been initiated. The NNORSC 4 proceedings addresses the six issues that need to be expanded according Rennie, Fehler, Dierking & Falk (2003) to understand learning at science centres:

- Examining the precursors to the actual engagement in learning
- Taking into account the physical settings where learning takes place
- Exploring the social and cultural mediating factors in the learning experience
- Promoting longitudinal research designs that recognize learning is cumulative
- Investigating the process of learning
- Expanding the variety of methods used to carry out our research

By addressing these issues the proceedings set a Nordic agenda for advancing research in science communication.

NNORSC 4 was gratefully supported by the EU-program Intereg IIIa Sønderjylland/Schleswig. These funds allowed the organizers to invite eminent plenary lecturers:

- Professor Lutz Fiesser, Flensburg University
- Co-director Chantal Barriault, Science North
- Professor David Pearson, Science North
- Professor Ilan Chabay, University of Gothenburg
- Dr. Justin Dillon, King's College London

The founders of NNORSC are hopeful that the NNORSC will evolve into a Nordic network of finding and sharing the best experiences, creating new collaborations; conducting new studies; reflecting on commonalities and differences.

Claus Michelsen, University of Southern Denmark, May 2008

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How do science centres perceive their role in science teaching? - An inquiry into science centres in the Region of Southern Denmark

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Recent research on learning outcomes from visits to science centres (Rennie et. al. 2003; Falk & Dierking 2000) suggest that stable learning outcomes of such visits require that such visits are (1) prepared in the sense that the teacher has introduced the students to the theoretical content expected to be touched upon during the visits, and (2) subsequently treated in the sense that the teacher builds on the individual students' experiences made during the visit. Typically such suggestions are conclusions drawn from surveys of visiting pupils and teachers.

In this paper we present a survey where the topic is approached from the perspective of science centres. We present the data of a survey of 11 science centres in the Region of Southern Denmark. The survey is the initial step in a project which aims, on the one hand, to identify the factors which conditions successful learning outcomes of visits to science centres, and, on the other hand, to apply this identification so as to guide the interaction of science teachers and science centres.

Interaction, Integration and Involvement

There are strong indications that science centres believe that successful visits require an interaction between centers and teachers (see Fig. 1). Teachers should play a part in the planning and execution of the visit. Further, the science centers indicate that successful visits to some extent depend on how well the visit is integrated in the regular teaching, and how well the visitors are prepared for the visit.

On the point "Identify and prioritize three criteria for a *successful* visit":

- 64 % pointed at the teacher's role as being among the top two criteria. More specifically these centers emphasize as important the degree of teacher preparedness, teacher involvement in the entire process, and the teacher's willingness to interact with the center.
- On the point "Identify and prioritize three criteria for a *failed* visit": Again the teacher's role was highlighted as being crucial. Examples of reasons for failed visits

include “poor communication [between] teacher and guide”, “when the teacher does not participate” and “when the teacher did not prepare the students properly”.

- It is mentioned that “teachers who are disinterested”, teachers who conduct “pleasure visits” compromise the successfulness of a visit

Fig. 1: Interaction, Integration and Involvement.

Reciprocal transparency

There are indications that science centres believe that successful visits to some extent depend on reciprocal transparency (see Fig. 2): While the teacher’s professional intentions with the visit must be transparent to the science center, so must the educational strategy of the center be transparent and familiar to the teacher. 73% of the science centres officially announce their educational strategy to teachers.

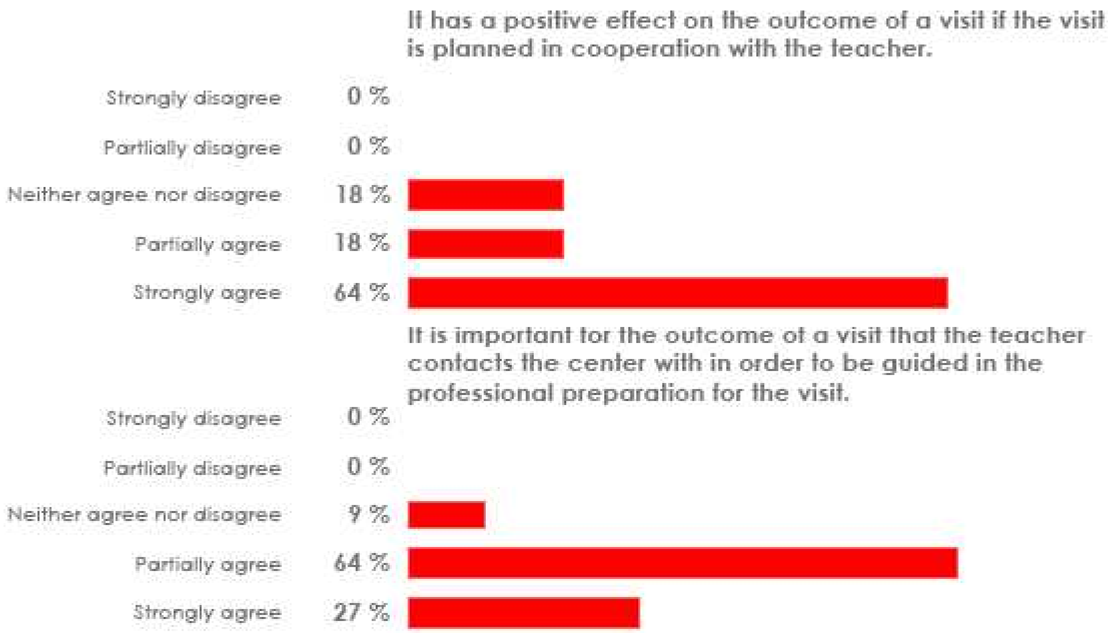

Fig. 2: Reciprocal Transparency.

Concluding remarks

According to Falk & Storksdieck (2005) factors such as prior knowledge, interest, motivation, choice and control, within and between group social interaction, orientation, advance organizers, architecture, and exhibition design individually influence learning outcomes, but no single factor is capable of adequately explaining visitor learning outcomes across all visitors. Needless to say, the science centres' own perception of their role in science teaching plays a vital role with respect to the successfulness of such visits. The data of our survey suggest that, also from the perspective of science centres, the degree of success of such visits is crucially connected to the degree of pre- and post-visit treatment on the side of the teachers: Successful visits require planned interactions between science centres and teachers. Being an initial step, this survey is to be followed by surveys in 2007 and 2008. Here we plan to survey 6-9 classes (pupils and teachers) immediately after a visit to a science center and follow up on these classes by surveying them 6 month later again. As a whole, these surveys hopefully brings us closer to identify the factors that play a part in successful learning outcomes of visits to science centres.

Acknowledgement

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Designing an innovative learning material about cloning

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Abstract

Lab to School is an international research and development project between Danish and German researchers of Science Education. The aim of the project is to investigate whether pupils' interest in science and technology can be enhanced by offering school classes a visit to research environments at the Flensburg University of Applied Sciences and the University of Southern Denmark. A problem often connected to out of school activities is that such activities form isolated experiences which lack a clear connection to the school curriculum in the eyes of the pupils. A part of the Lab to School Project is to develop interdisciplinary learning material with the purpose of making a connection between an out of school activity and the school teaching. This article will describe and discuss the design of such a material, in our case a material with 'cloning' as the main topic - and relate it to learning and the development of situational interest towards a science topic. Furthermore we will describe the intention of the material being a tool in integrating an out of school experience with teaching in the classroom.

Introduction

"*I doubted at first whether I should attempt the creation of a being like myself, or one of simpler organization…. The materials at present within my command hardly appeared adequate to so arduous an undertaking, but I doubted not that I should ultimately succeed.*" These lines are from Mary Shelly´s famous book "Frankenstein"[1]. The "I-person" is Dr. Frankenstein and he did succeed by creating a monster. In 1996 a group of scientists under the direction of Ian Wilmut also succeeded with their work – they created a clone of a sheep. Six month later the sheep called Dolly was presented to the public.

These two stories do not appear to have anything in common, but if you integrate them in a learning material about cloning, you can make a bridge between the fictive world and the real world – and a bridge between different subjects in school. Our material is intended for the Danish Upper Secondary School, and the aim was to design a material, which could be used in integrating an out of school experience with the teaching in the classroom. We emphasized that the topic should be an up-to-date topic. Cloning is indeed a topic that has caught the attention of the press and the public the last years.

Our motive for the design has its origin in a new reform of the Danish Upper Secondary School implemented in 2005. One of the key points in the reform is that pupils, to some extent, must be taught in an interdisciplinary fashion. Our material relates to cloning from four different subjects - biology, mathematics, history and social science. It is therefore directly applicable in an interdisciplinary setting/course. In addition the biology chapter is designed in a

1 Shelley's novel was first published in 1818, but has been published numerous times since then.

way that a visit to a research laboratory at a University is necessary and therefore relevant for the pupils.

Our ideas originated from a project, Lab to School, which is an international research and development project between Danish and German researchers of Science Education. The aim of the project is to investigate whether pupils' interest in science and technology can be enhanced by offering school classes a meaningful visit to research environments at Flensburg University of Applied Sciences and University of Southern Denmark. In addition one of the main purposes of the project is making a link between the science pupils learn in school and science in the real world – in this case science in a laboratory at Universities. With the cloning material we have developed a tool which hopefully can make this link.

Designing the learning material

To combine all the subjects in this learning material we made a narrative (a fictive story), which along with cloning unites the chapters. We were inspired by Jerome Bruner, who argues that we store our memory as narratives (Bruner, 1987). Much of what we remember is tied to a story. Not only is a story a tool for remembering. It is also a tool for comparing and categorizing. Bruner argues that narratives are used to connect different domains of human knowledge and thereby creating transfer from one domain to another (Bruner, 1991). Narratives can therefore be seen as a very powerful tool in creating a higher understanding of a topic. It makes it easier for the pupils to see the relevance of the topic – in this case 'cloning'. This is the main argument for us to use the narrative approach in the learning material. By using a story to combine the different subjects, we believe that the pupils will be able to remember it later on. One can say that we rely on narratives to create a transfer from one course to another.

The connecting story in the material is about a journalist, who participates in a conference about cloning. He has to write an article about the topic from a biological, mathematical, historical and a social science point of view. Through the learning material the journalist attends some talks, gets new knowledge from books and discusses aspects of cloning with other conference participants. The learning material contains topics from the subject's biology, mathematics, history and social science. Each chapter represents a subject to one course and can stand alone or in combination with one or more of the other chapters – the focal point through the entire material is 'cloning'. The material is designed to offer a high level of "teacher ownership".

In designing the material the aim was not only to integrate the subjects in school, but also to integrate the teaching in school with a visit in a research lab at Universities. School visits – such as trips to museums, science centers or universities – has a tendency to become isolated events without any further integration to the school curriculum (Rennie & McClaffety, 1996;

Anderson & Zhang, 2003; Anderson, Kisiel & Storcksdieck, 2006). This lack of integration between the visit and the school practice often influence the impression of the visit with regard to pupils' interest. The aim of the out of school experience regarding our learning material is that the pupils before visiting the laboratory worked with the material. In the laboratory they then have to do a PCR experiment ('Polymerase Chain Reaction', a technique used in microbiological experiments) and by so doing find an answer to the fictive story in the learning material. Thereby they get a chance to understand some of the processes involved in cloning, the visit will be meaningful for the pupils and hopefully they will get a positive impact of science in general.

Combining theory of interest with theory of learning

A positive impact as mentioned above could be seen as interest development. An interest starts with a triggered situational interest sparked by e.g. character identification (Hidi & Renninger, 2006). By using a curious, but not all-knowing science-journalist as the main character in the story, it is our aim that the pupils will identify with him, and thereby get their interest triggered. In order to maintain the interest the topic must be meaningful in the eyes of the pupils (Hidi & Renninger, 2006). We therefore introduce the topic of cloning to the pupils with for example emotional, ethical and social considerations. By using the narrative approach we hope to build a platform for the pupils to develop at least a situational interest for the topic. Empirical studies regarding the use of this material will in the future give us more knowledge about how the pupils find the cloning material in combination with the visit to a laboratory.

In the process of designing the learning material it was important for us to make it interesting not only to the pupils but also to the teachers. In order to make it interesting to teachers there has to be a certain part of learning perspective in the material. In this part of the paper we therefore will discuss the learning angle.

In the following we give a short introduction to learning theory in combination with interest developing theory as it often is difficult to relate to the one without the other.

Learning theories often has a one-way approach to learning seeing learning as one of two metaphors, acquisition or participation. Sfard (1998) argues that learning cannot be seen as one or the other, but must be seen as a combination of both metaphors. A learning theory could therefore be seen in the way that Illeris sees it (Illeris, 2006). Here learning consists of both an acquisition in the individual between cognition and emotion and an interaction (which could be

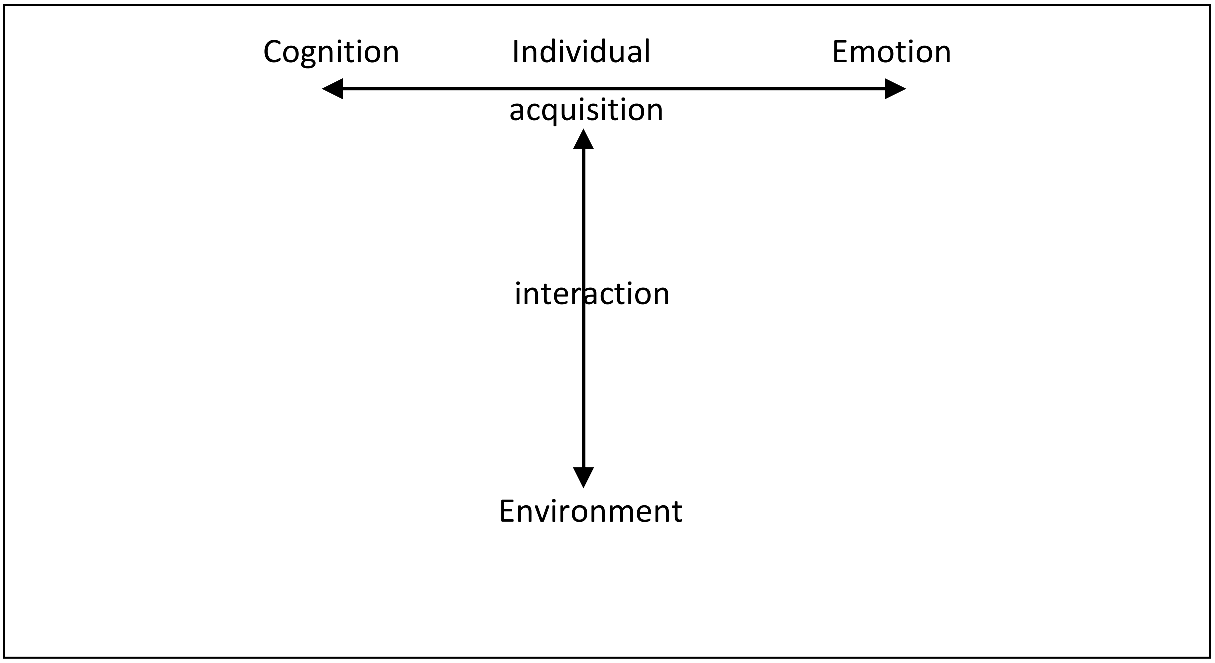

Fig 1: The fundamental proces of learning (Illeris, 2006).

placed under the metaphor participation) with the environment (Fig. 1). In this way one can construct a triangular field of learning between cognition, emotion and environment. The dimension of cognition is where the learner constructs knowledge and abilities in order to develop an overall personal functionality. The dimension of emotion is the one that encompasses mental energy, feelings and motivations.[2] It functions by securing a mental balance and thereby developing a personal sensibility. Finally the dimension of environment is seen as the dimension of participation, communication and co-operation. This serves the personal integration with others and builds up the sociality of the learner.

The field of learning is placed inside a society in which the learning takes place (Fig. 2). The society is always the frame of the field of learning, but the triangular field of learning can be different from society to society. However, it is important to notice that the learning always contains both the individual acquisition of learning and social construction of participation no

2 The field of motivations is a broad area of research and theories that we will not describe further in this paper.

matter which society we are dealing with. In the case of our teaching material we reach out to the public concern about cloning and biotechnology.

By introducing emotional, social and cognitive challenges to the pupils we hope to create a link to their everyday society.

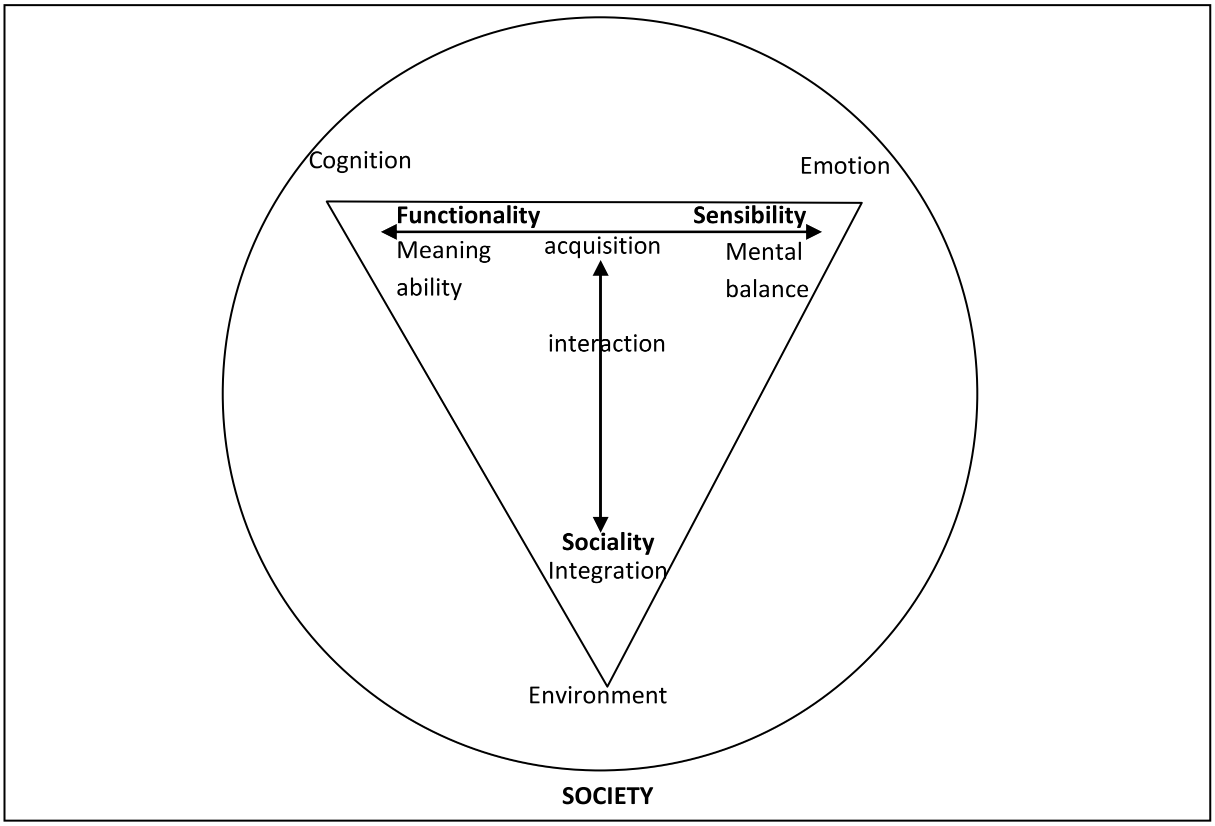

Fig. 2: The processes and dimensions of learning (Illeris, 2006)

As mentioned earlier, it is not the main purpose of the learning material and the visit to a laboratory to enhance learning. Instead it is that the pupils hopefully will develop a situational interest for a science topic and see how science is used outside the school. If we combine the theory of interest development (TID) with this theory of learning, the model for the learning theory can be used as a frame for this interaction. It is though important to keep in mind that the model is a dynamic model and that it should be seen as a 3-dimensional model rather than the 2-dimensional model just shown.[3]

In TID the first impact is an interaction between environment and emotion. The catch starts with an external object that triggers some kind of emotional response. In order to

3 In the combining of interest development theory and learning theory we thank Dr. Professor emeritus Andreas Krapp for personal comments.

hold the interest there must though be a cognitive dimension (Krapp, 2002). This is where the connection between the emotional dimension and the cognitive dimension comes in to action. This could lead to a maintained situational interest, but in order to do so there must be a continuous input from the environment. That is where the 3-dimensional model comes in. One can now see the model as a container being filled up with inputs from the environment, the emotions and the cognition. Thereby the learning is an output of the developing interest.

Our learning material should therefore be seen not as a material, which provides the teachers an instrument of how to teach, but as a learning material which provide the pupils the opportunity of learning through developing an interest.

Empirical testing of the learning material

The next step in the process is to test the cloning material in Upper Secondary School classes and evaluate the whole course. How do the pupils respond to the learning material? Does the integration of working with cloning in the classroom and a visit in a laboratory at the University have any impact on the pupils? Does it trigger a situational interest for the topic 'cloning'? Can the fictive story help triggering a situational interest? And do the pupils actually learn anything from working with this learning material? The intention is also to look at the teachers and see how the material can be used in different ways. Our hope and belief is that the pupils find the learning material and the out of school experience in the laboratory interesting and relevant. In this way the pupils might see natural sciences in a broader and a more positive perspective.

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Supporting Learning: Assessing the Visitor Learning Experience Through Research in Science Centres

Chantal Barriault
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Science North opened its doors to visitors in 1984 with a unique approach to the visitor experience. Open, public laboratories and staff scientists engage visitors in the investigation of scientific concepts with real tools and hands-on activities. The role of a staff scientist at Science North is to design, develop and deliver exhibits, workshops, school programs and activities that engage visitors in the discovery and exploration of science as it relates to everyday life.

The effectiveness with which we accomplish this mission is challenging to assess beyond anecdotal evidence and science centre professionals around the world often struggle with this. When visitor studies in science centres and museums began in earnest in the 1990's assessment methodologies included primarily "time spent at an exhibit" and measurements of knowledge or facts retained from interacting with the exhibit. It can be argued that these assessments reflected the goals of the exhibit designers and didn't take into consideration the learning experience from a visitor's point of view. If facts are not retained, does this mean that the visitor has not learned? Many researchers in the field therefore began calling for a different approach to assessing the learning experience in science centres, including Falk and Dierking (1992, 1998), Ramey-Gassert, Walberg & Walberg (1994), Rennie & McLafferty (1995). Studies in learning have since enabled us to better understand what is involved in the learning process and what the key factors are in maximizing learning opportunities.

With a clearer understanding of how learning occurs, it is possible to observe and listen to visitors interacting with exhibits in order to assess the effectiveness and the impact of those exhibits on visitor learning. The goal of this paper is to describe an evaluation tool developed and used by Science North (Barriault, 1999) to assess the visitor learning experience and to inform exhibit design based on the results of this assessment. Grounded in constructivist learning theory, the Visitor-Based Learning Framework and the Exhibit Assessment and Modification Model have proven to be effective in informing best practice at Science North while encouraging a culture of research and self-evaluation among the staff who work there.

Understanding Learning: the making of meaning

One of my favourite definitions of learning was written by Wittrock in 1977:

"Learning is changing through experience…. Acquiring a relatively permanent change in understanding, skills, knowledge and attitude through experience."

It is now well established in learning research that learning is an active process of the construction of meaning. People are no longer viewed as passive recipients of knowledge but as active participants in their making of meaning. In the constructivist approach to learning, prior knowledge, prior experience, motivation and interest play a key role in the learning process (Hein, 1998)

In their landmark book, The Museum Experience, Falk & Dierking (1992) introduced the Contextual Model of Learning which was a comprehensive look at the learning experience in informal environments. In 2000, Falk & Dierking re-visited and elaborated the model to what is now called The Contextual Model for Free-Choice Learning (see Figure 1). The rationale behind this model is that "…all learning is situated within a series of contexts - not some abstract experience that can be isolated, but an organic, integrated experience that happens in the real world" (Falk & Dierking, 2000).

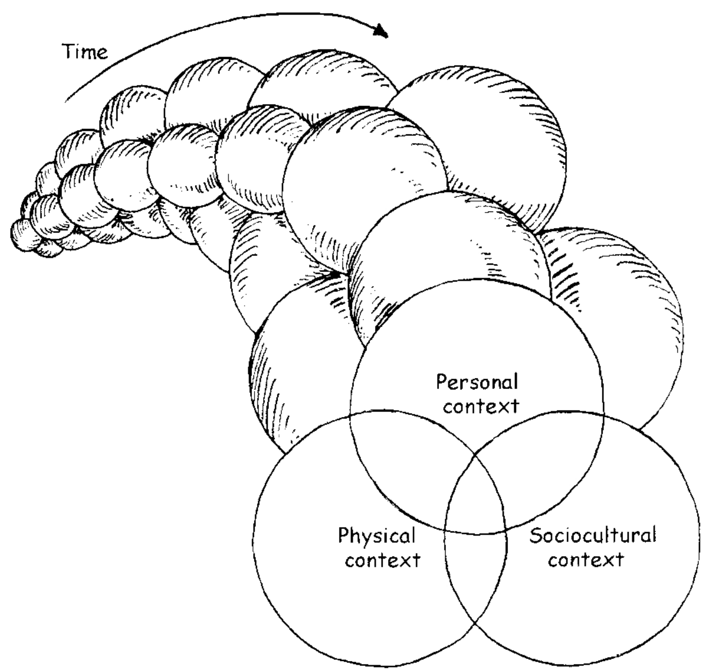

Fig. 1: The Contextual Model of Free-Choice Learning. Falk, J. & Dierking, L. (2000)

Their model was derived from observations of visitors in informal settings and involves 3 overlapping contexts, the personal context, the sociocultural context and the physical context. Learning, according to their model, is the process and product of the interactions between these three contexts through time.[4]

In summary, the personal context refers to the influence of prior experiences, prior knowledge, interest and motivation and emotional cues on the visitor's learning experience. The sociocultural context emphasises the important role of shared knowledge and experience and the community of people that help shape the meaning we make from our experiences. Finally, learning occurs in a physical space and, as expressed by Falk & Dierking (2000), "what we learn is tightly bound with our memories of place".

The Science Centre Learning Experience: A visitor-based framework

The difficulty with measuring learning outcomes of science centre visits is that these outcomes are often judged against indicators that are predetermined by the exhibit designers. These predetermined lists might fail to capture the individualistic nature of learning, hence the role of existing knowledge in making meaning from one's experiences.

In 1998, I investigated learning from a visitor's perspective, observing their behaviour as they interacted with exhibits to determine if there were consistent patterns of behaviours that occur which indicated or suggested that learning was indeed occurring. Constructivist theory and the Contextual Model of Learning informed the grounded theory approach to data collection and analysis (Barriault, 1999).

The study produced an analytical and practical visitor-based framework of learning behaviours which are grouped into three levels according to what I refer to as the 'depth' of learning that occurs or the level of engagement of the visitor. The framework is found in Table 1.

The Learning Behaviours

Initiation behaviours (Doing, watching others engaging, information or assistance offered by others) indicate that visitors are *taking the first steps towards a meaningful learning experience. Even though visitors are not yet completely involved in the experience, they are gaining some level of information through the experience which in turn, could lead to more learning.* Initiation behaviours enable visitors to 'test the waters' with minimum personal risk and provide an entry point into further learning opportunities offered by the exhibit.

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[4] For a complete description of the Contextual Model of Learning, refer to Falk & Dierking, 2000; for an abbreviated but thorough description, refer to Braund & Reiss, 2004, pp. 115-119)

Transition Behaviours (Repeating the activity, expressing a positive emotional response): Smiles and outbursts of enjoyment along with repetition indicate that a level of comfort has been achieved and that visitors are comfortable, and even eager, to engage themselves more thoroughly in the activity. Regardless of whether the activity is repeated in order to better understand it, to master the functions or to observe different outcomes, the net outcome is a more committed and motivated learning behaviour.

Breakthrough Behaviours (Referring to past experiences while engaging in the activity, seeking and sharing information, engaged and involved: testing variables, making comparisons and using information gained from the activity): Each of these behaviours acknowledges the relevance of the activity, and the learning gained from the activity, to the individual's everyday life. A personal level of comfort has been established that encourages a free flow of ideas and exchanges, and enables real learning to occur.

Learning behaviour	*Depth of Learning*
Doing the activity	**Initiation behaviours**
Spending time watching others engaging in activity	
Information or assistance offered by staff or other visitors	
Repeating the activity	**Transition behaviours**
Expressing positive emotional response in reaction to engaging in activity	
Referring to past experiences while engaging in the activity	**Breakthrough behaviours**
Seeking and sharing information	
Engaged and involved: testing variables, making comparisons, using information gained from activity	

Tab.1: Learning behaviours and the depth of learning at exhibits

Using the Framework: Observing visitors interacting with an exhibit

The Visitor Engagement Profile (VEP)

This visitor-based framework is a useful tool in understanding the visitor learning experience for individual exhibits. The patterns of behaviour become a framework for taking a closer look at how visitors are engaging with exhibits. Based on what we know about the process of learning and key influences on maximizing the potential for learning, we can infer that these behaviours are indicative of the learning process. An observation plan, as seen in Table 2, provides science centre staff with a practical tool to evaluate the effectiveness of a particular exhibit or an experience with a cluster of exhibits. Data is collected through observations of visitor interactions and analysis of visitor conversations, either in person or through video recording.[5]

Observation Plan for Visitor Engagement Profile

Exhibit name : **K'nex Race Track**

Date of Observation: ***22-Jun-07***

Behaviour	Age Group	Initiation Behaviours			Transition Behaviours		Breakthrough Behaviours		
Subject (description)		Doing the Activity	Observing others	Support or Assistance by others / staff	Repeating activity	Positive emotions	Acknowledge relevance	Seek/ share info	Involvement / Engagement
1. Boy, green shirt, hat	7 to 10	¦		¦	¦		¦		¦
2. Man, yellow coat	30's		¦	¦					
3. Girl, red trousers	5 to 7	¦	¦			¦			
4. Woman, grey blouse	60's		¦			¦	¦		
5. Man, blue hat	40's	¦			¦			¦	
6. Boy, orange jacket	13 to 15	¦	¦	¦	¦	¦			¦
7. Boy, blond, blue coat	5 to 7	¦	¦				¦		
8. Woman, glasses,	40's		¦	¦					

Tab. 2: Sample observation plan used at Science North to record visitors' behaviours while they interact with an exhibit.

5 Visitors are informed of all observations and video recording through information signs that are posted throughout the study area of the science centre.

This information is then quantified into a graph I call the Visitor Engagement Profile (VEP). Figure 2 is an example from research done at Science North with exhibits in our Body Zone exhibition. The y-axis represents the percentage of visitors who engaged in the depth of learning behaviours on the x-axis. Such a profile can be created for individual exhibits and shows the learning potential of that particular exhibit. Plotting the observation data into a VEP makes it more visual for staff involved and allows us to interpret the results by looking at the curve for each exhibit. Notice that the Initiation behaviours column is at 100%. This is result of the fact that only visitors who approach the exhibit are observed or 'counted'. The VEP is not intended to be a measure of attracting power because of the challenge of assessing the reasons why particular visitors did not approach the exhibit. Instead, the VEP focuses our attention on the learning behaviours demonstrated by visitors once they have made the commitment to engage with the exhibit.

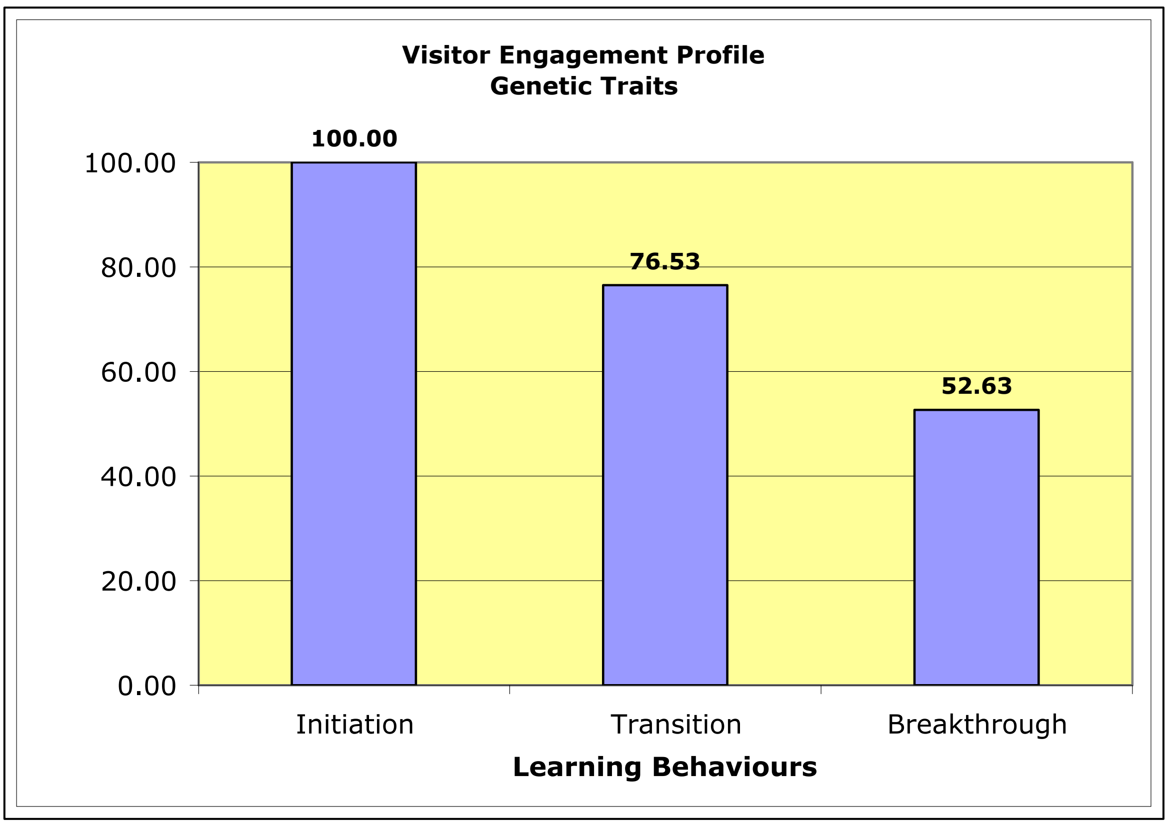

Fig. 2: An example of a Visitor Engagement Profile taken from a research study conducted at Science North in the Body Zone exhibition.

An ideal curve in the VEP graph is really quite dependent upon the type of exhibit being assessed. For example, if an exhibit is created to be placed at the entrance to a larger cluster of exhibits, to simply introduce people to an idea or to attract them to come in, science centre staff may be satisfied with a VEP that has 30% of its visitors demonstrating *Transition Behaviours* and 10% of its visitors demonstrating *Breakthrough Behaviours*. However, an exhibit designed to really involve visitors in variable testing, hypothesizing, and in meaning making dialogue should produce a VEP with at least 50% of visitors demonstrating *Breakthrough Behaviours.*

The Exhibit Assessment and Modification Loop

Creating VEP graphs from observational data is an important part of the feedback loop that informs staff and exhibit planners at the science centre about the learning opportunities that are or are not present in the exhibits. As previously mentioned, if an exhibit's Visitor Engagement

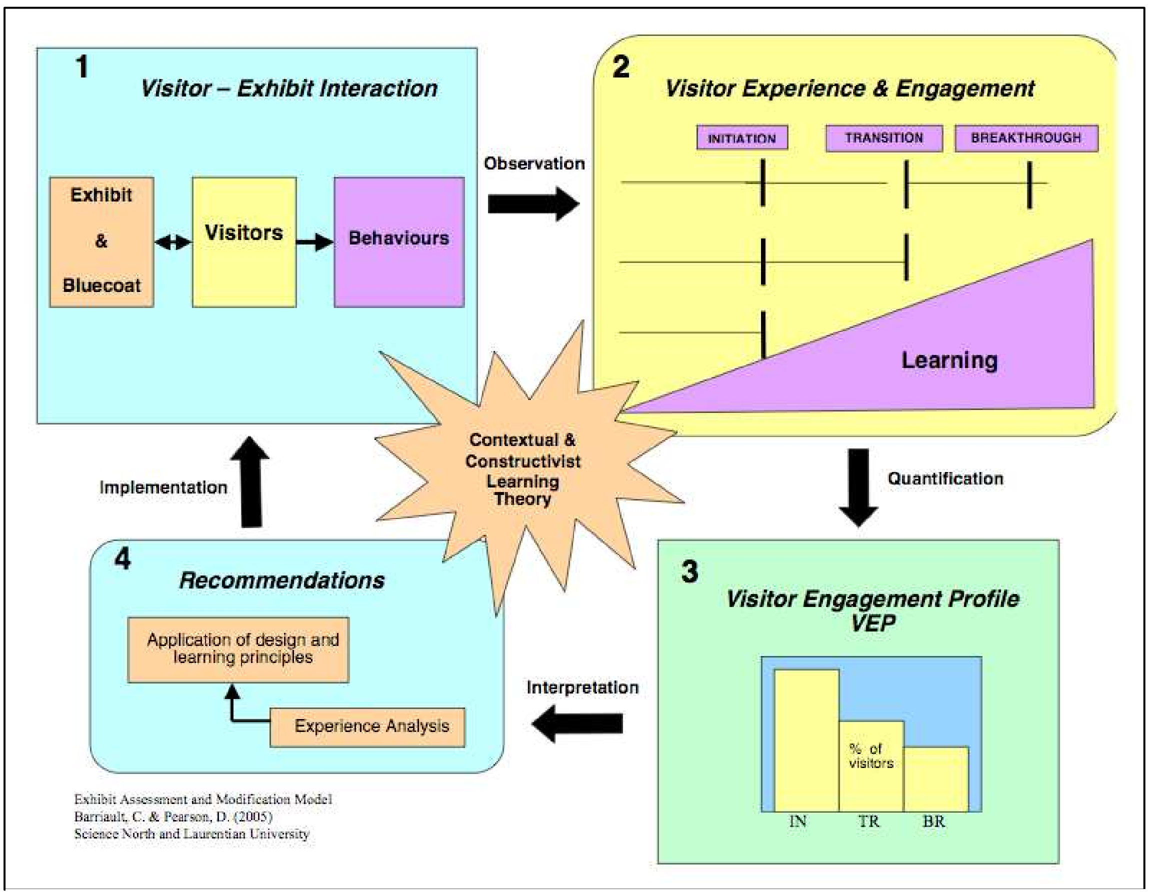

Fig. 3: Exhibit Assessment and Modification Feedback Loop used to improve the learning opportunities of exhibits.

Profile has a low curve but was expected to engage visitors at a deeper level of learning, this sends a warning bell to staff and exhibit developers. Staffs hence have an opportunity to analyse the exhibit from a visitor's point of view, and in the end, to make modifications to improve the VEP. An example of such activity at Science North illustrates the Exhibit Assessment and Modification Loop (Figure 3).

The Sprint Track at Science North is an exhibit that was first introduced in the Human Machine special exhibition in 2004. It is a 10 metre sprint track with starting blocks where visitors are timed when they reach the end of the track. A video coach and a replay video of the visitor encourage participants to improve their exit out of the starting blocks, like professional athletes would do in an actual race. The VEP (Figure 4) for Sprint Track showed good levels of Transition behaviours and visitors clearly showed high levels of enjoyment (positive emotional responses) and repeated the activity often. The Breakthrough Behaviour levels weren't quite as high as expected, suggesting that visitors were not taking full advantage of the learning opportunities presented by the exhibit. For example, although the video coach and the play back option are intended to encourage visitors to make changes to their positioning to improve their time out of the starting blocks, these exhibit features were not used by visitors as often as hoped.

In 2005, the Sprint Track exhibit was redesigned and moved to its permanent home in the Body Zone Lab. Figure 5 shows the Visitor Engagement Profile for the Sprint Track after changes were made to improve the learning opportunities. Based on observations of visitor interaction, constructivist learning approaches and physical design considerations, changes were

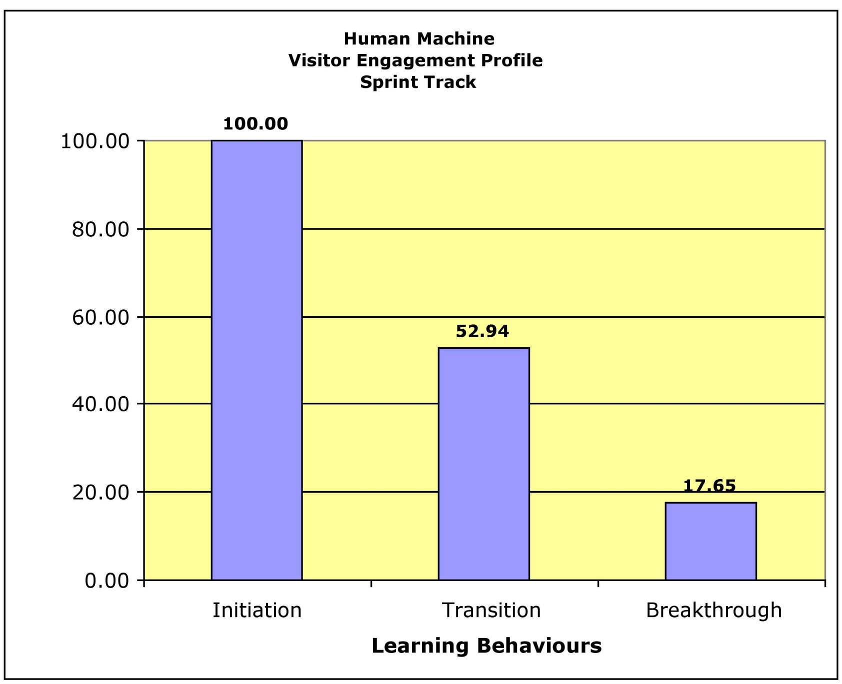

Fig. 4: Visitor Engagement Profile for the Human Machine Sprint Track Exhibit in 2004, before design changes were made to improve learning opportunities.

made to the exhibit and observations were made to create a new a VEP. In short, the video coach and play back monitors were repositioned and improved signage encouraged more involvement from visitors. These changes proved beneficial. Both Transition and Breakthrough behaviours increased.

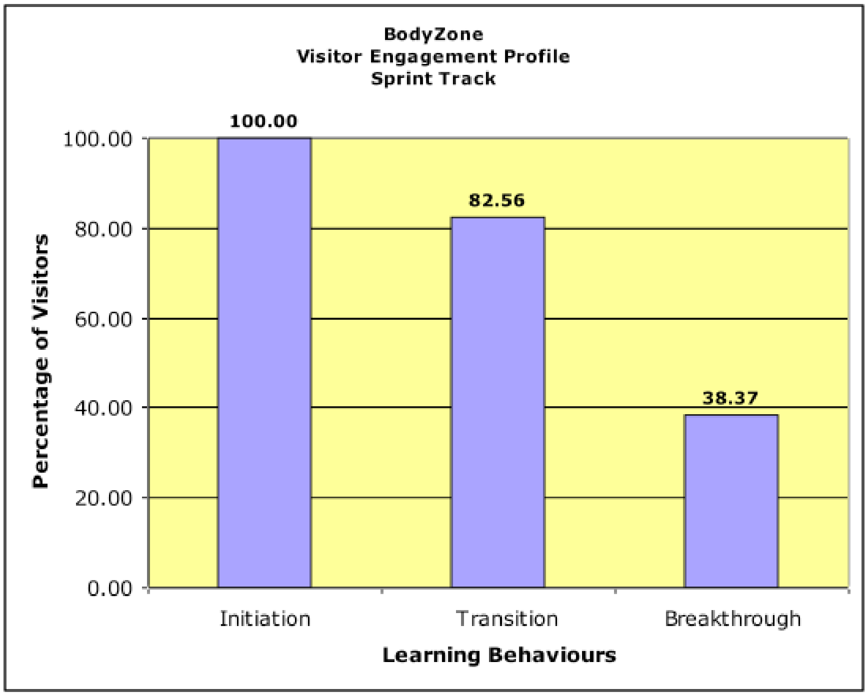

Fig. 5: Visitor Engagement Profile for the Body Zone Sprint Track Exhibit in 2005, after design changes were made to improve learning opportunities.

Research Culture and the Empowerment of Staff

The use and application of the Visitor-Based Framework, the Visitor Engagement Profiles and the Exhibit Assessment and Modification Loop have proven very beneficial to Science North in a variety of ways. For the visitor, the result of this research activity means better exhibits that provide more learning opportunities. For the science centre's staff scientists, the use of these tools enables them to make improvements to the visitor learning experience offered by their exhibit. It also empowers staff scientists to use data, not just intuition, to make changes to exhibit design while fostering a research culture that encourages reflection in developing the visitor experience.

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Science Theater as a Way of Communicating Biophysics to Students in Upper Secondary School
Does it trigger a situational interest among the students?

Stinne Hørup Hansen

> *"Why not use drama to smuggle (with a substantial dose of theatricality) important information, generally not available, into the minds of a general public?"*
> (Carl Djerassi, professor of chemistry emeritus at Stanford University. Author of short stories, poetry and two autobiographies as well as of five novels and eight science-theater-plays.)

Introduction

Science Theater Plays are increasingly staged in order to improve public understanding and appreciation of science and to communicate a scientific topic that is difficult to understand but highly relevant to the public. But what is the "interestingness" of the plays? What is the purpose of the plays? How is the audience affected by attending a Science Theater Play? And what is the possibility of affecting audience attitudes towards science through Science Theater? These questions have not yet been addressed. This PhD-project will shed light on some of these aspects with respect to students in Upper Secondary School as the audience and in connection to the particular Science Theater Play on biophysics titled: "The Magic Bullet". In this paper I will give a brief introduction to the genre "Science Theater", and then I will elaborate on the Science Theater Play "The Magic Bullet" with particular emphasis on the "interestingness" of the play. Finally I will introduce my preliminary results from interviews of students from Upper Secondary School who have watched the play.

Science Theater

Science Theater is often thought of as a new phenomenon, but the use of theatrical techniques to communicate science has quite a long history. In the seventeenth and eighteenth centuries in Europe groups of 'natural philosophers' traveled the roads and gave lectures that were often accompanied by startling demonstrations, particularly of the new discoveries in electricity. Standards varied: some had real scientific value, others were little more than fairground attractions. The entertainment value was appreciated and the more charismatic figures became the darlings of high society.

Whatever their scientific value these lectures were some of the first attempts to communicate the new scientific discoveries to society. And from the outset theatrical techniques added style and flair to the presentations. In early nineteenth-century England Michael Faraday, a scientist still renowned today for the precision of his experimental methods, was profoundly convinced of the need to communicate both the wonder and the methods of science to the general public. The Christmas Lectures he instituted at the Royal Institution, which are still held today, were carefully crafted presentations which combined scientific accuracy with dramatic stage effects. In the nineteenth and twentieth centuries, as science became increasingly specialized and its effects on society more and more pervasive, a gulf began to arise between public and scientist. This made it clear that there was a need for informed public debate.

Among the many initiatives undertaken in the late sixties and seventies, mostly in England and the U.S.A., a number of small theatre companies, supported by bodies dedicated to promoting the public understanding of science, began to experiment with new techniques of communicating science. Nowadays new trends are emerging and science theatre is developing: Tom Stoppard's play "Arcadia", and Michael Frayn's "Copenhagen", to name just two, demonstrate that serious scientific themes can appeal to the public. And the 'dramatized lectures' at the Soppteater in Stockholm, in which renowned scientists are on stage together with actors, prove that scientists need not be afraid that theatre will distort and cheapen their work. The theater director of "The Magic Bullet" describes Science Theater in the following way:

> *"The principal idea of Science Theater is to make use of the theater's ability to give insight and realization through narratives. We involve artistic means when constructing the scenery and through the cooperation with researchers, art is combined with the reality that takes place at the universities here and now."* (Nørgaard, 2007)

Following this historical development of Science Theater we are, in my opinion, left with three primary categories within the Science Theater Genre. The first category includes plays about scientists either famous or unknown with a story illustrating the progression of scientific work done in the laboratory resulting in knew discoveries and possibly affecting culture and society. The people on stage are actors and the play is most often written in collaboration between scientists and professional playwrights. Examples that fall under this category are, as mentioned earlier, Michael Frayn's "Copenhagen" and Tom Stoppard's play "Arcadia".

Another category is science theater where real scientist are on stage playing their own real life character as a scientist. These types of plays have a high level of scientific content and illustrate how they make use of former discoveries in order to make new discoveries, giving the theater play a historical and scientific content. This is the category in which "The Magic Bullet" belongs.

The third category is what you could call performed science where scientific experiments are carried out in front of an audience with the purpose of both entertaining and teaching the audience about scientific phenomena. Several universities have "Science Shows" that visit schools or companies and share their joy for the sciences. As an example students at the Southern University of Denmark offer both a "Chemistry Show" and a "Physics Show".

"The Magic Bullet"

"The Magic Bullet" is a fairytale from the real world. It is about the research behind the invention of a sphere of fat, the bullet, which can smuggle chemotherapeutics into the body, find its way to the cancer tissue and release its poisonous content without harming the healthy tissue. The play is performed by three scientists playing their own character as a researcher; a professor in biophysics (Ole G. Mouritsen), a PhD. student in molecular biology (Anne Kallesøe Bugge) and a master student in medicine (Jonas Hedegaard Andersen). The play was instructed by Bent Nørgaard from the Center for Science and Arts. During the play the audience is introduced to the historical aspects and breakthroughs leading to where the research is today namely ready to begin the clinical trials. Main emphasis is on the need for interdisciplinary cooperation and the engagement and curiosity that urges the researchers on.

A reviewer of the play wrote the following:

"To be honest it really is what you could call a documentary play blended with theatrical effects, but unfortunately with a total lack of dramatic nerve and evolvement which could have turned it into theater. You simply miss a Script Writer's creative strength.

Even though you still leave the Theater with speculative wrinkles on your forehead and a smile on your lips, because the potential is obvious…." (Aagaard, 2007)

I included this review to give the reader an idea of the public's experience with the play.

1 Interest and interestingness

Lauren Gundersen, a renowned playwright, states that, "as an educational tool, science theatre has opened up a new avenue to grab student' interest." (Gunderson, 2006).

Generally, people working with science theatre refer to the plays as interest triggers. In the following I will give a brief overview of the concept of interest according to *Krapp et. al.* and the term interestingness. After the introduction to interest I will analyze the play with respect to its interestingness and with a further description of three didactical tools used in the play.

According to Krapp et al., interest is conceptualized as a specific relationship between a person and a topic, an object, or an activity, which is characterized by positive emotional experiences and feelings of personal relevance. Interest has both cognitive and affective components (Krapp *et al.*, 1992). There are two states of interest, individual interest and situational interest. Individual interest is a relatively stable interest associated with positive emotions and effortless attention. It is part of the individual's personality and gives rise to interest-oriented actions. By maintaining this special relation with an object the interest is further developed (Hidi *et al.*, 1992). A person can experience a manifestation of the individual interest, which is comparable to the experience of a situational interest. Situational interest, on the other hand, is a short-term phenomena related to the interestingness of a particular situation. It is generated in the learning environment under conditions that trigger interest and can serve as the basis for the emergence of an individual interest. The term interestingness is used to describe the interest triggering potential embedded in the situation. Interestingness depends on the student and his/her background, the students' individual social environment, the content and the involvement, the material and the means of communication. Greatest interestingness is found in situations that deliver information in forms of narratives, which is surprising, novel, and intense, of high personal relevance, with character identification and which generates an emotional impact. Situational interest in a learning situation can help maintain focus and facilitate learning even within topics that are not generally of interest to the student.

2 The interestingness of "The Magic Bullet" – three didactical tools

Dramaturgy

The play has a dramatic composition inspired by the ups and downs that characterize research in the laboratory. Several obstacles are described; solutions are presented leading to several dramatic climaxes. Then with small twists the solution results in new problems to be solved. The following is an excerpt of the play describing how researchers work hard to make sure the liposomes are tight:

Anne:

"When you use the liposomes for cancer treatment, they obviously have to be injected into a human body in which the conditions are much more complex than what we can reconstruct in a test tube. Since we do not know exactly what our liposomes will be subjected to inside the body we need to make sure that they are stable and tight, so the cell poison doesn't get out before they have found the cancer tumor."

Ole:

"Luckily we can solve that problem because we are physicists and chemists and we might not know that much about the biology in details and maybe our liposomes find areas that we didn't know about. But you must remember that we are the engineers behind the liposomes. Which means that if they are not tight but leaky, under certain circumstances, we simply go back to the laboratory and change them. We are now able to exploit our knowledge about the chemistry and physics of the liposomes in order to make them tight – when they need to be tight. We have a whole lot of buttons to turn (adjust)….."

…

"Alas, it is not all that easy. Now we have worked hard to make the liposomes tight and make them circulate in the bloodstream, but now they are so tight that the medicine can't get out at all – how do we find the key to unlock them? (Translation by the author)

The dramaturgic climax in this extract is when the researchers succeed in making the liposomes tight – the obstacle is that the liposomes are so tight that the poison cannot get out when it reaches the cancerous tissue. Finding the key is the next problem to be solved.

Role models

At the end of the play a screen on the stage shows interviews with the scientist where they describe how they generate ideas. We are told that one of the researchers also gets ideas when she spends time with her boyfriend, and reflects on that as being "unsexy". Another researcher explains that standing in line in the supermarket gives her too many chaotic inputs to generate ideas. These reflections make the researchers human as it reveals aspects of the "non-scientific" part of the researchers' lives. This is in accordance with Gunderson's description of Science Theater:

"The best scientific characters do all the things that make us human, not just the things that make us brilliant. So it is not enough for me to show you scientists doing science; I need to show you *why* they do it." (Gunderson, 2006).

When actors become human, character identification becomes easier for the students and that is important with reference to the theory of interest where character identification plays a role in the triggering of a situational interest.

Personal relevance

The creation of a potential cure for cancer is a topic of personal relevance to the majority of the audience. Apart from this the scientists, in particular the physicist, makes references to everyday terms and experiences while describing the generation of the fat sphere. An example of this is found in the following excerpt:

"As we all know from the kitchen, there are compounds, such as olive oil, which, when we mix them with water, separate. They are unmixable with water. They hate water. We call them hydrophobic…."

The monologue makes reference to everyday experiences which enables the audience to relate to the information. The researcher even describes olive oil as a compound that *hates* water giving it feelings and hereby facilitating the understanding of hydrophobic compounds' reluctance to blend with water.

Research question

In light of the didactical tools incorporated in the play I expect the students to experience a situational interest or a manifested individual interest. I want to investigate what particular aspects of the play have the greatest potential to trigger an interest in the individual student and to analyze the impact of this experience of being interested. This leads me to my research question:

What is the students' in Upper Secondary School subjective experience with the play?

Several methods have been used to investigate the answers to this question.

Methods

This is a brief overview of the methods used to address my research question.

- Questionnaires for assessment of the students' relation to natural sciences before watching the play
- Self-report measures of affective reactions to the science theater play (Ainley, 2002)
- Self-report measurement of the interestingness of the science theater play
- Field interviews with students and groups of students to asses the immediate reactions to the science theater play
- Individual interviews of the students within three days of watching the play

In this paper I present the results from the field interviews of three students from three different levels in Upper Secondary School and analyze the comments with respect to the knowledge obtained from interviews of the individual students.

Results

Below are notes from three field interviews immediately after watching the play. I regard them as exemplary of students from the particular level in Upper Secondary School.

3rd level student, girl

”Totally great! Really really great. Repetitive. The information level was neither too hard nor too easy. Not boring at all. Really great!”

2nd level student, girl

”Interesting. Good informations. A little boring to me. More acting would have been better. But it was good information.”

1st level student, boy

”Very interesting. I was expecting more acting, like a real theater play. The way it was performed was a bit boring. I would have preferred a real lecture. …I actually (smiling) told my parents all about it when I came home.”

3 (translation by the author)

The 3rd level student watched the play with her class of advanced biotechnology and she has a stable individual interest in biotechnology. Her prerequisites for watching the play were very good and it is obvious from the reaction that this student had a fantastic experience from watching the play. Her individual interest in the topic was manifested during the play and she experienced a mastering of the terms and the ability to understand the scientific content of the play. This experience has confirmed her interest in biotechnology and possibly moved it further up the “ladder of interest” (Krapp, 2002, Hidi & Renninger, 2006). She finds it very likely that she in 10 years time will be a researcher like those on stage.

The 2nd level student watched the play with her biology class and has a relative stable individual interest in biology. She clearly found the information in the play interesting, but the form of communication was a bit boring. She was expecting more acting as in a real theater play. Her disappointment with the form of communication dominates her experience with the play.

The 1st level student watched the play with his physics class. As the 2nd level student he was disappointed with the form of communication. He has a stable interest in the natural sciences; hence he did not feel that he needed the forms of Science Theater to communicate the scientific content in order to trigger his interest and keep his attention. According to him it would have been sufficient to learn about the research from a regular lecture. As he watches the play in a school context, he evaluates the play with respect to learning and in that regard he finds it more efficient with a regular lecture. The last comment confirms that he found the scientific story interesting and worth telling his parents. During the interview I asked him to tell me about the play and in his summary he showed mastery of the play's scientific content at a reasonable level.

All students found the scientific content of the play interesting; hence the interestingness of the play is obvious. Presenting research in natural sciences as a narrative with relevance to the general public *is* interesting. However, according to the results of the interviews presented above it is questionable whether the form of communication in this particular Science Theater Play is supportive to the content of the play or possibly even obstructive to the scientific message. It is clear that the expectations towards the play as being a real theater play have a noticeable impact on their reception of the play. This problem might be solved by presenting the form of the play properly to the students and addressing their expectations towards a Science Theater Play on beforehand.

Future

The students' prerequisites for watching the play and individual interest towards the scientific content of the play influenced their reception of the play. Further analysis of my results can presumably enable me to categorize the students with regard to interest and their prerequisites for understanding the play and predict how a particular student relates to the play. Further research could lead to knowledge about how a particular subject within the natural sciences should be communicated in order to give the individual students an experience comparable to the experience the 3rd level girl had from watching "The Magic Bullet".

The play contains an enormous amount of information that can be addressed during science lessons after watching the play. In my opinion the play should not stand alone, if the impact of the play is to be improved or maintained.

Carl Djerassi a renowned "science-in-theater" playwright recommends other means of dissemination of a science theater play rather than a book publishing, namely making the plays available on DVD's or videocassettes. This form of dissemination has been applied to "The Magic Bullet". It has been produced into a DVD and I have developed two kinds of teaching materials so as to facilitate internalization of the play in the students' own practice. A "light" version which constitutes a trail with 9 tasks that takes approximately 2½ hours and a "heavy" version where students in groups are to write a small report on one of the central topics of the play. In the future I will investigate the potential of "The Magic Bullet" on DVD in combination with one of the two follow-up versions of teaching material.

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The making of a national science event: The Festival of Research in Denmark

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Abstract
The Festival of Research in Denmark is an annual national science event intended to "arouse public interest in and enhance public understanding of the methods, processes, and outcome of research and science". The event is coordinated and partly funded by the Danish Agency for Science, Technology and Innovation. As such, the festival forms part and parcel of the recent, national emphasis on research communication. This paper situates the Festival of Research in the context of national research policy, the international science events movement, and current debates among research communication scholars about models for current research communication. Stressing common objectives while also aware of ambiguities, this paper emphasizes the multi-faceted character of informal science events such as the Festival of Research.

Introduction
At noon on 27 April 2007, the third annual Festival of Research in Denmark began. During the following 24 hours, in all of the major and in many smaller cities all over Denmark, some 225 research communication activities and 57 public lectures took place. The activities included science cafés, research market places in shopping centers, technology quizzes, science competitions, open house arrangements at the universities, and an eye-catching opening event featuring minister for science Helge Sander and HRH The Crown Prince. Having just returned from the round-the-world Galathea 3 Expedition which combined cutting-edge research with on board, on-line research communication, the naval vessel *Vædderen* paid a final visit to Odense. On the occasion, the Communication Department of the University of Southern Denmark and Odense ZOO recreated some of the places visited by the expedition. A few researchers that had participated in the expedition gave lectures, and biologists took samples from Odense harbor to compare them with samples taken on the Galathea 3 Expedition.

Obviously, the Festival of Research in Denmark provides various audiences with the opportunity to think about science and research. Similarly, they are settings in which researchers may engage with the general public in many different ways: from public lectures to shopping-related conversations in the research market place to public debates in science cafés to children's games and competitions. The Festival of Research is a heterogeneous research or science communication event that, like other such events, generally exist in order "to market science positively", and "to increase the status and attraction of scientific work and to recognize scientific results" (Bohm et al., 2005).

Importantly, besides research and science communication most science events also feature other kinds of communication such as institutional communication and political communication. In the following, by drawing attention to the political and national context, I wish to elucidate the brief history and social context of the Festival of Research. I will pursue the argument that, an outcome of the attempt in Denmark to increase and improve the quality of research communication, but also to change the agenda from public appreciation of science to science in society, the Festival of Research embodies many of the inherent ambiguities in current debates about science and research communication (Miller, 2001; Miller, 2001; Sturgis & Allum, 2004).

On the one hand, research communication events such as the Festival of Research are entangled with political communication, i.e., politicians trying to frame current political debates in terms of more funding of research and innovation and more public communication about research. From this perspective, research communication is all about increasing public trust in science, allowing for researcher's to show off the glory and wonders of their craft. On the other hand, the Festival of Research implements ideas about increasing the dialogue between science and society. The effect of this kind of dialogue-based communication is unclear at the moment since evaluations and analyses seldom rarely adopt the two-way communicative framework (Bauer, Allum, & Miller, 2007). It does appear, however, that the scientific issues and research agendas involved in this kind of research communication would be different from those normally used. For example, publicly controversial themes such as cloning (Horst, 2005), scientific border issues such as complementary medicine and cold fusion (Simon, 2001), scientific controversies (Young & Matthews, 2007) and other cases involving socio-scientific issues (Grace & Ratcliffe, 2004) seem to be more fitting for this particular agenda of research communication. To be sure, the Festival of Research comprises such issues, but also traditional topics from the world of research results and methods.

National context: the Think Tank on public appreciation of research

The ongoing Festival of Research results from the recent attention giving to research communication by the Danish Government. As such, they are part and parcel of the Government's strategic communication of research and research policy. The idea for the Festival of Research was first proposed by minister for science Helge Sander who, in May 2003, established a think tank on research communication. The think tank preceded the modification of the Act on Universities to include research communication as a third university obligation besides research and teaching (Ministry of Science, Technology and Innovation, 2003). The new Act on Universities aims at increasing collaboration between research and innovation, while also strengthening public communication of research. According to the terms of reference, the think tank was to:

- formulate policies for research communication

- expand and develop the public understanding of the importance of research with respect to society, industry and the individual citizen
- try out new ways of reaching broader segments of the populations, such as organizing the Day of Research (Ministry of Science, Technology and Innovation, 2004).

Originally, the Day of Research was Helge Sander's idea. In November 2002, Anne Katrine Holst, public servant of the Ministry of Science, suggested to Sander's press officer that the ministry should take an interest in research communication (A. K. Holst, interview, June 11, 2007). The minister then ordered a memorandum on public communication of research prepared by Holst and colleague Karen Laigaard. Their memo put forward ideas about TV shows on research, ministry-based campaigns on research, etc. Sander, who himself knew almost nothing about the world of science and research when, in 2001, he was appointed as minister for science, liked the proposal. Having toured all of the Danish universities after his appointment, he was very impressed with the ability of researchers to communicate what they were doing in an interesting way. He firmly believed that science and research could and should be communicated to all segments of the population, even at the local village hall. And he wanted more people to share his newly found appreciation of research. Moreover, he was certain that Danish Parliament would hesitate to allocate more money for research if the general public remained indifferent to science and research. Consequently, in early 2003, he launched the Ministry of Science's project on public appreciation of research, proposing a national day of research where researchers would visit all of the "village halls" in Denmark narrating their research to the general public (Kjærgaard, 2006).

The think tank formed part of the Ministry's project on public appreciation of research and, among other things, was to elaborate on the minister's idea of a national Festival of Research (Ministry of Science, Technology and Innovation, 2004; K. H. Nielsen, 2005). The explicit purpose was bringing the concept of research "down to earth" by giving the public insight into the importance of research for future welfare, environment, health and growth. It was argued that, traditionally, public communication of research was lacking because, on the one hand, researchers prefer communicating directly with each other and, on the other, the mass media generally had very little interest in communicating scientific research. The role of the think tank was to provide some middle ground between these two extremes. Here, it seemed, was where new means of research communication such as the Festival of Research would come together with increased public appreciation of science.

The think tank consisted of 26 members, most of which were journalists and communicators employed at public organizations. With a professional background in communication and politics (for a while, she was the spokesperson on science and research for the Socialist People's Party), Christine Antorini chaired the think tank. Acknowledging the somewhat strange lack of representatives from the world of science and research, Antorini and the rest of think tank requested from the Danish Center for Studies in Research and Research Policy a report on science communication. The report surveyed best practices in European science communication and summarized the Center's previous work on public opinion about research (Aagaard & Mejlgaard, 2003). One of the report's conclusions was that, generally, public interest in research and science is relatively high and has been growing for the past 15 years or so. In 1989, about 50 per cent of the people asked indicated high or moderate interest in research; in 2000, the percentage was about 75 (Aagaard & Mejlgaard, 2003). This seems to be consistent with the findings of recent Eurobarometer public opinion polls (Directorate General Research, 1993; Directorate General Research, 2001; Directorate General Research, 2005).

Moreover, the report distinguished between three kinds of research communication, passive, active, and social research communication, respectively (Aagaard & Mejlgaard, 2003). Passive research communication takes place through the mass media which people consult in order to obtain information on a broad range of subjects. The research communication achieved in such cases, perhaps with the exception of specialized programs and sections on science and research, usually is a kind of by-product of the people's consumption of the mass media. It is passive in the sense that it does not involve active search for information on scientific and research-related issues. Active research communication, to the contrary, happens when people themselves take the initiative in consulting more specialized media for research communication such as technical journals, monthly science magazines, science books and lectures, etc. Finally, social communication about science and research is the information you get in conversations with friends, colleagues, and family. The report noted that active and social research communications have risen whereas there is a slight decrease in passive research communication.

The think tank used the report's conclusions in its own final report (Ministry of Science, Technology and Innovation, 2004). Firstly, it was recognized that there is no current shortage of research communication. However, most research communication takes place in the context of one-way, linear communication of knowledge from the expert community to the general public. Acknowledging the democratic commitment to get citizens to feel involved in technological and scientific issues, while also recognizing the need for the universities and other research institution to maintain social trust in science and research, the think tank promoted the view that what was really in demand was two-way communication between science and society. Also, the think tank wanted to detach research communication from the designated science pages in the newspapers, from the science programs on TV and radio, and from the special science events, and to make research communication a natural part of all other kinds of communication in society. In other words, in effect the think tank rejected the "public appreciation of science" or "public understanding of science" agenda put forward by the Danish Government in favor of the "science in society" or "science and society" framework currently adhered to by many European countries and by the European Union (Bauer et al., 2007). Consequently, the think tank seemed to be a bit skeptical towards the national research day proposed by Helge Sander.

Constructing the first festival of research 2005

The think tank put forward a total of 27 recommendations, some of which were more ambitious with respect to shifting the political agenda for research communications than others. Despite some reservation, the think tank recommended pursuing Helge Sander's idea of a Day of Research by initiating an annual, 24-hour Festival of Research for trial period of five year. Even though Sander's idea of flooding the village halls with researchers was not really the kind of two-way dialogue between science and society that the think tank had ended up calling for, the national research day did form part of the terms of reference for the think tank.

For organizational, financial, and personal reasons, the Festival of Research became anchored in the Ministry of Science. The National Science Week in Norway, which served as an inspiration, is planned by The Research Council of Norway with its large and specialized communications department. Since, at the time, The Danish Research Councils had no similar organizational structure taking care of outreach and communication activities, but also since the minister personally took a keen interest in the project, it was decided that the first Festival of Research was to be enacted by a secretariat consisting of employees of the Ministry of Science. Two persons were employed full time for six months on the project, and one person half time for six months. They all had no or very little experience in planning and carrying out larger, strategic communication campaigns. Therefore, they hired the communications firm Bindslev AS as process consultant (A. K. Holst, interview, June 11, 2007).

On advice from the facilitator employed by Bindslev, Sine Egede, the ministry-based secretariat for the Festival of Research invited four professional communicators for a so-called inspiration seminar to contribute to the planning of the event: Christian Have (Have PR & Kommunikation), Nadia Pass (the magazine *Reflexioner*), Asger Høeg (Experimentarium) and Claus Bindslev (Bindslev AS) (A. K. Holst, personal communication, September 24, 2007). Even though the Ministry's internal budget for the Festival was very limited, after this seminar it was agreed upon that the Ministry should organize and sponsor a few activities. In part, the Ministry wanted "to create a framework of communication for the Festival of Research"; in part, to make sure that, at least, some activities were being held (Secretariat of Festival of Research, 2005). Claus Bindslev and, later, Gert Balling of the Danish Science Cafés, played an important role in getting together some of the Ministry's "own" activities. The activities were to be given to the host municipalities, see below. It was important that these activities were designed to capture the attention of people who wouldn't otherwise think about attending a research communication event. The secretariat wanted people going out to "enter into the world of research" (A. K. Holst, interview, June 11, 2007).

Inspired by conversations between well-known author and literary critic Johannes Møllehave and his heart surgeon Gösta Pettersson, Claus Bindslev came up with the notion of "Exclusive Conversations" in which researchers would enter into dialogue with a well-known public figure. The latter would act as a kind of representative of the broad population and ask interested, yet challenging questions to the researcher. The conversation was to be set in a cozy, intimate and unconventional setting. Also, the Ministry made plans for six Science Cafés on robots around the country (Gert Balling's idea), Science Theater shows in Odense (organized by the Center for Art and Science at the University of Southern Denmark), a Science Night at Experimentarium in Copenhagen, an opening event organized by Bindslev AS, which involved EuroPhysicsFun and was held at the central railway station in Copenhagen, and the presentation by Crown Princess Mary of the newly instituted Science Communication Award for researchers (another recommendation of the think tank). Finally, the Ministry arranged for the independent, non-profit organization Danish Science Communication to establish the "order a researcher" program by means of which local groups paying only for travel expenses could order a researcher to come give a lecture (Secretariat of Festival of Research, 2005). The "order a researcher" program, which was modeled on a similar program called "order a lecture" for the national science festival week run also by Danish Science Communication, was very similar to the original idea proposed by Helge Sander, getting as many researchers as possible out in the village halls.

The activities organized by the Ministry of Science were to be supplemented by many local activities. All of the Danish municipalities (271 in total) were asked to host the Festival of Research locally. From eighteen favorable responds, ten municipalities were selected as host municipalities. They were to coordinate their own input to the Festival of Research with an emphasis on hands-on activities. Moreover, all of the universities and many other research institutes and research-based companies were asked to join in the action. At first, the organizers at the Ministry were somewhat surprised by the positive respond received and the considerable, local interest in the event (A. K. Holst, interview, June 11, 2007). A homepage was established to publish and coordinate the many events all over the country.

The first Festival of Research took place on Thursday 12th of May 2005. It comprised around 284 local activities in addition to 98 lectures from the "order a researcher" program and the above-mentioned activities enacted by the Ministry. On a national basis, the Festival of Research 2005 drew a crowd of around 20.000 people. Generally, the evaluation performed by the Ministry concluded that the event as such was "a success". Based on questionnaires, the evaluation report established that most of the local organizers were quite satisfied with the event and wanted to organize activities again for the 2006 Festival of Research. However, there was some criticism of the limited time available for the organizers to put together and to make public the activities. Also, less than 50 per cent of the local organizers believed the turnout was satisfactory, and they generally blamed the Ministry for failing to promote the event locally as well as nationally (Secretariat of Festival of Research, 2005). Since the secretariat had encouraged the local organizers to seek publicity for their own events, it was concluded that, in planning the following Festival of Research, attunement of mutual expectations was needed (A. K. Holst, interview, June 11, 2007).

In order to supplement the data from the questionnaires, the secretariat for the Festival of Research held an evaluation meeting with the contact persons of the ten host municipalities. It turned out that there was a clear difference between the resources spent. The host municipalities chose to spend between DKK 5.000 and DKK 150.000 on their participation in the Festival of Research. Most of the municipalities had appointed an employee to work full time on the project for some time. Those that had not had experienced some difficulties in getting the ends to meet. There was a clear correspondence between the resources spent and the outcome. Interestingly, the municipalities also differed in terms of where they decided to anchor the local secretariat for the Festival of Research. Some placed it in the business and innovation department; others in the department of education. In contrast to the local organizers, most of the municipalities were quite satisfied with the overall marketing of the Festival on behalf of the Ministry. Some, however, wanted the Ministry to be much clearer about the intended target groups (Secretariat of Festival of Research, 2005). The strategy of "letting a thousands flowers bloom", more or less implicitly pursued by the secretariat, turned out to be too blurred in the eyes of some of the host municipalities (A. K. Holst, interview, June 11, 2007).

Finally, an evaluation meeting was organized with representatives of the research institutions. The secretariat had found that there were many employees at these institutions who shared a genuine and long-lasting commitment to research communication. These persons welcomed the Festival of Research as it lent ministerial support to their own activities. Moreover, it supplied them with an arena for research communication that many felt had been missing (A. K. Holst, interview, June 11, 2007). Consequently, most of the persons present at the evaluation meeting soon agreed that the basic concept of the Festival of Research was sound. However, there was criticism to be heard. The research representatives generally seemed to quite skeptical about activities "that led researchers round by the nose", i.e., show-like, public events with very little focus on actual research. Also, echoing the critique put forward by the local organizers and the host municipalities, some called for more publicity on behalf of the Ministry, and some wanted increased focusing on particular target groups (Secretariat of Festival of Research, 2005).

Keeping the momentum: the Festival of Research 2006 and 2007

With the relative success of the 2005 event, for the subsequent years it was up to the organizers to keep the momentum without being too repetitive. In some ways, the Festival of Research 2006 closely followed the model of the 2005 event. However, in contrast to the 2005 event, all of the Danish municipalities were invited to join in and those that wanted to were welcome (S. I. Bondy Jørgensen and K. Plousgaard, e-mail correspondence, September 19, 2007). Again, the secretariat arranged for some activities to be held: The Researcher Challenge (researchers competing with each others on solving the world's energy problems within twenty-four hours) and "order a researcher". Whereas the overall concept for the 2005 event was to "demonstrate the importance of research for our everyday life" (Secretariat of Festival of Research, 2005), the 2006 event chose "on the track of the future" as a common theme (Secretariat of Festival of Research, 2006).

Since many of the organizers of the 2005 activities had been somewhat skeptical about the weekday chosen for the event (Thursday), for the 2006 event it was decided to try out the period from noon on Friday the 5th of May to noon the day after. This, however, caused problems for some of the local organizers as they found that many people, on their day off, were too busy minding their weekend affairs to take an interest in research. Also, in all of Denmark, Friday the 5th of May 2006 turned out to be a really nice and warm spring day (one of the first of the season) and, so, there were a lot of other pleasant things for people to do (like sitting in the sun) besides attending research communication activities. In particular, some of those arranging indoor activities on Friday afternoon such as for instance, lectures and science cafés had to cancel simply because nobody turned up. Around 40 per cent of all organizers were dissatisfied with the number of audience attending their activity. Still, this figure represented an increase in comparison to the 2005 event where some 60 per cent of the organizers expressed dissatisfaction with the turn-out. In fact, the general turn-out for the 2006 event was estimated to be around 30.000 people, which represented a marked improvement of one-third in comparison with the 2005 event (Secretariat of Festival of Research, 2006).

In total, the Festival of Research 2006 comprised 294 registered activities including 180 "order a researcher" lectures of which 151 were carried out. As had also been the case for the 2005 event, the Ministry supplied all of the organizers with t-shirts, poster template, stickers and electronic files containing the logos of the Festival of Research. It was made clear to all of the organizers that they alone were responsible for promoting their activities locally, whereas the secretariat would only inform the press about the event in general and the activities prepared by the secretariat, in particular the Researcher Challenge. Even so, as had been the case in the evaluation of the 2005 event, there was some criticism on the lack of national as well as local marketing of the event. Moreover, there seemed to be correspondence between those organizers who felt that the event had not been properly announced and those who didn't want to become an organizer for the Festival of Research 2007 (Secretariat of Festival of Research, 2006).

The Festival of Research 2006 differed from the 2005 event in that the secretariat only organized two activities. Whereas, in 2005, the Exclusive Conversations and the Science Cafés were "given" to the host municipalities, in 2006 the municipalities had the opportunity of applying for funds to do their own activities.

In 2006, the Ministry of Science underwent a major reorganization during which the secretariat of the Festival of Research was relocated to the Agency of Science, Technology, and Innovation. In many ways, this new organizational location matched the nature of the event. It meant that the secretariat suddenly found itself right next to the secretariat of the Research Councils and, thus, closer to the actual research in demand by the event (A. K. Holst, interview, June 11, 2007).

In January 2007, Stefanie I. Bondy Jørgensen was appointed as head of the secretariat (S. I. Bondy Jørgensen and K. Plousgaard, interview, June 11, 2007). Previously, she had been working as project leader of the well-known cultural event, the Night of Culture, in Copenhagen. The two events have the same umbrella-like structure in that they both provide overall structure in terms of an open organization, common graphic identity, a combination of central and local marketing, plus a joint calendar for a number of very different and scattered activities. Moreover, they share the same ambition. The two events differ in the sense that the Night of Culture in Copenhagen is a local event, whereas the Festival of Research is nation-wide, which means that the marketing of the event poses quite different challenges to the organizers (S. I. Bondy Jørgensen and K. Plousgaard, e-mail correspondence, September 19, 2007). (Another difference is that whereas all Festival of Research activities have to be free, you have to purchase a so-called Culture Pass in order to attend the activities on the Night of Culture.) The Night of Culture takes place in many different Danish cities each year on the Friday before the national school autumn holiday in week 42. It comprises many activities organized mainly by local cultural institutions and organizations. The event aims "to arouse cultural curiosity and to stimulate the ability of cultural experience in adults and children" (Night of Culture, 2007).

When Bondy Jørgensen joined the Festival of Research secretariat, the planning of the 2007 event was already well underway. It had been decided to follow the structural organization of the past two years with a few central activities prepared by the secretariat, a number of host municipalities (as many as possible) organizing and running activities on a more regional basis, activities planned by the universities and national research institutions, and, finally, the "order a researcher" program prepared by Danish Science Communication. In order to inspire local organizers to come up with new formats for research communication, primarily based on dialogue activities and new means of presenting science to the general public, a pool of money (DKK 400.000) was offered. Except for private companies, everybody in principle was free to apply for support. It turned out, however, that there was little competition for the funding. The secretariat required the activities to involve collaboration between organizations and to have at least 50 per cent co-funding. Moreover, the activities had to be free, open to the general public and to involve dialogue in some way (S. I. Bondy Jørgensen and K. Plousgaard, interview, June 11, 2007). With one exception, the pool funding was given to the host municipalities and to universities, research institutions, and museums. Still, the total pool of funding was not used (S. I. Bondy Jørgensen and K. Plousgaard, e-mail correspondence, September 19, 2007).

As stated in the introduction, the 2007 event involved 225 activities besides 57 "order a researcher" lectures open to the general public and around 120 closed lectures. In their evaluation, the secretariat made a decision to focus less on the total number of people attending the event and, instead, to concentrate on the experiences of the organizers. By means of questionnaires, the secretariat established that 88 per cent of the organizers felt quite happy about participating in the Festival of Research whereas two-thirds was content with the turn-out for their event. For the 2007 event, there had been a slight change of date from early May to late April (Secretariat of Festival of Research, 2007)

Moreover, an effort was put into getting the organizers to feel a larger degree of ownership of the event. As had been the case in the previous years, the only real requirement communicated by the secretariat to the organizers was to have all of the events in the joint, web-based calendar. Other than that, and the expressed wish to use the graphic design of the event as a kind of common eye-catcher by using as many t-shirts, poster and stickers as possible, there were no constraints for the organizers – within the limits of communicating research-based knowledge. As it turned out, private companies increased their involvement in the event. Among the host municipalities, there was a slight shift in anchorage from the departments of education to the departments of business and innovation. A few municipalities even outsourced the involvement in the Festival of Research 2007 to local firms. In the municipality of Odsherred, for example, the local research-based, pharmaceutical company organized for local school groups to visit the company, to carry their own "research projects" using the company's resources, and, then, on the day of the Festival to communicate their "results and methods" on the premises of the company. The worldwide and world-leading Danish wind turbine manufacturer Vestas also was very visible in that the company had placed big screens and exhibitions in all of the major cities in Denmark. The secretariat welcomed the presence of such activities as long as they didn't degenerate into pure PR. The secretariat believed that inclusion of well-known companies and product-based research communication proved to be a way of "making research more relevant to all kinds of people and not just those already interested in science and research" (S. I. Bondy Jørgensen and K. Plousgaard, interview, June 11, 2007)

Conclusion: research communication for the future?

To sum up, the Festival of Research started out being the idea of minister for science Helge Sander who really wanted scientists and researchers out in the village halls; then turned into one of the recommendations of Sander's think tank on public appreciation who called for more dialogue and the implementation of the science-and-society agenda for current research communication; and now lives a life of its own, so to speak, run and organized by the secretariat of the Festival of Research placed in the Danish Agency of Science, Technology, and Innovation. It appears that the idea has gained enough momentum to continue beyond the trial period. Following next year's Festival of Research, an evaluation of the first four years will be performed, and, based on the positive experiences so far, it seems as if the event stands a good chance of becoming a permanent feature within the field of research communication in Denmark; very much like the Night of Culture mentioned above that, since 1993, has become generally accepted and well-liked by the general audience and by cultural organizations alike.

The event combines traditional deficit model-like thinking about research communication (the researcher in the village hall) with more up-to-date concepts such as public engagement, science citizenship and general science education for all. As such, it is very hard to pin down with one model. This may be a trivial, yet important lesson to all of us trying to conceptualize research communication. The more involved and engaged we try to become, the harder it is to maintain an analytical viewpoint. It may also be a common feature of many, if not most informal science events.

The Festival of Research brings together various kinds of interests. The Festival is attractive form the point of view of politicians such as Helge Sander who uses the Festival to promote the current research and research communication policies of the Government. Also, knowledge-based institutions such universities and firms may use the event to communicate their activities and resources to the local community, but also to future students, employees, and partners. Furthermore, the event provides an opportunity for societies, organizations, and firms that specialize in various kinds of (research) communication such as the Danish Science Communication, the Danish Science Cafés, and communication agencies to expand their range of assignments in this particular field.

As such, the Festival of Research keeps alive by balancing organizational heterogeneity with individual ambitions on behalf of the many organizers and common branding of the event. The heterogeneous nature of the event, like many other science events, eventually makes the research communication produced in the course of the Festival more socially robust than other kinds of more narrowly defined research and science communication (Nowotny, Scott, & Gibbons, 2001). However, the necessity of including institutionalized research while increasingly also taking into account knowledge applied in commercial and industrial settings makes the Festival vulnerable to forgetting more critical, perhaps even alternative approaches within the field of science and research. Even though I personally would like to see the Festival continued on a regular basis, I still would maintain that it remains to be seen whether the Festival of Research and similar science events are viable ways of communicating research for the future?

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The effect of different task formulations on children's work habits

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Introduction

Scientific approach

In order to examine the effect of different task formulations on work and learning habits of children, two different methods of investigation were used– one in the PHÄNOMENTA and one in school. According to this approach, Type I- and Type II-task formulations were developed. Type I-tasks were very clearly defined, while Type II-tasks briefly presented an experimental problem.

Methodical approach

One of three experiments was offered each day the PHÄNOMENTA was open to the public. Alternately both types of task were presented to the test subject. Having finished, they were given transfer tasks in order to examine whether or not their experiences led to profound learning processes. In addition to that, an observation sheet was used to record the test subject's methods of working on the problems. These methods were then divided into categories which allowed conclusions about the success of learning processes.

In a further survey, two groups of students from 8th grade were provided with the two types of differently formulated tasks. Their methodical approach was recorded on camera and encoded via "videograph" afterwards. The children's behaviour was again assigned into categories.

Course of the examinations

a) PHÄNOMENTA:

In the PHÄNOMENTA investigation the following experiments have been offered to the test persons. Using type-II task formulations an experimental problem – like a question - was offered and different kinds of materials were given to the examinees. Using a type-I task, the test persons just got the materials they need and a clearly defined instruction.

1. Egg in the bottle: Try to get an egg into a bottle without damaging it.
2. Blowing up a bag: In this experiment the test persons have to blow up a cotton-bag which is stitched on each side.

3 Fishing an ice cube: The test persons have to find a way (to reach a solution) to get an ice cube out of water() without getting whet fingers.

Using Type-II tasks the test persons got the following question for the first experiment: „*Is it able for you to put the egg into the bottle without damaging it?"* Different kinds of materials were offered on a table, for example: vaseline, a funnel, an egg-pricker, a toy-hammer and matches.

To find a solution for this experimental problem the test person has to use prior knowledge and its creativity. Using a type-I task the instruction was very clearly defined and the test persons just got the materials they need to do the experiment.

1." Light a match and put it into the glass bottle."
2." Quickly put the egg with the pointed side down on the opening of the bottle."

In order to examine whether or not their experiences led to profound learning processes, they were given transfer tasks. For example:

"*You want to save your summer clothing during the winter. Therefore you take a plastic sack and put your summer clothing in it. Afterwards take a vacuum cleaner to suck the air out of it. What will happen?"*

1. *The clothing is suck into one corner of the plastic-bag so you got space for more clothing.*
2. *The sac becomes very small and covers the clothing.*
3. *The clothing gets dust-free, but nothing happens to the bag.*

To establish the effect of using different types of task formulations a combination of observation and transfer task was used. In this examination the following observation-sheet was used. This observation-sheet is especially suitable to observe learning habits in science centers, because it can be used independent of age and experience of the test person.

<table>
<tr><th colspan="3">Categories to judge work and learning habits</th></tr>
<tr><td>A</td><td>Observing others experimental work.</td><td rowspan="3">CATEGORY I:
"attention"</td></tr>
<tr><td>B</td><td>Looking at the experiment.</td></tr>
<tr><td>C</td><td>Active experimental work.</td></tr>
<tr><td>D</td><td>Showing positive reactions.</td><td rowspan="3">CATEGORY II:
"perception/awareness"</td></tr>
<tr><td>F</td><td>Asking questions about the experiment.</td></tr>
<tr><td>G</td><td>Repeating parts of the experiment.</td></tr>
<tr><td>H</td><td>Going into the experiment.</td><td rowspan="2">CATEGORY III:
"understanding"</td></tr>
<tr><td>I</td><td>Testing variables.</td></tr>
</table>

K	Asking for more information.	
L	Using experience.	
M	Leaving experiment after a short time.	CATEGORY IV: "negative reactions"
N	Breaking off the experiment at an early stage.	

Tab. 1: Categories to judge work and learning habits

The categories I to III show increasing participation in the experiment and increasing depth of learning. Category IV records negative reactions of the test persons.

b) Group of 8th grade students in school

In a further survey, two groups of students from 8th grade were provided with the two types of differently formulated tasks. The beginning of the lessons was the same in both classes. First they were shown several pictures of salt mines and () a chunk of a salt-sand-crystal. The exercise was to split up a salt-sand-mixture.() One group had a task I formulation – which was very clearly defined – the other group a type II formulation. Both groups were provided with the needed equipment.

Type I:

Fill up the salt-sand-mixture with as much water as needed to dissolve all the salt. Pour the mixture through a tea strainer (first) and afterwards through a funnel with filter paper in it. Catch the filtrate in a glass. Heat the filtrate as long as the whole water is boiled away and you receive back the salt.

Type II:

Develop a plan to solve the following problem:
You get a salt-sand-mixture. Separate the mixture in its parts.

While the pupils were doing the experiment their (experimental) behaviour was recorded on video.

The following hypotheses were formulated and verified in this investigation:

- *Less detailed types of tasks stimulate examinees to work both creatively and independently .*
- *Active and very bright examinees show a more positive attitude to work when confronted with less determined test conditions.*

To look into the work and learning habits the observed conductions have to be coded. Therefore a category-system called *„pupil working habit“* was developed for this examination. This system can be divided into 8 action-categories, which can be observed objectively. Time phases of each pupil from both classes are coded with the observed action-categories.

„pupils working habit“

Category	Activities
1	Reading the task.
2	Talking about the experiment.
3	Doing the experiment.
4	Looking to the place of happening.
5	Writing down observations.
6	Asking the teacher or other group / looking at other groups experiment.
7	Activities which don't belong to the lesson.
8	Other activities.

Tab 2: Category system: “pupils working habit”

The following illustration shows the software program „videograph“ which has been developed by Rolf Rimmele at the IPN in Kiel. This program was used for the coding.

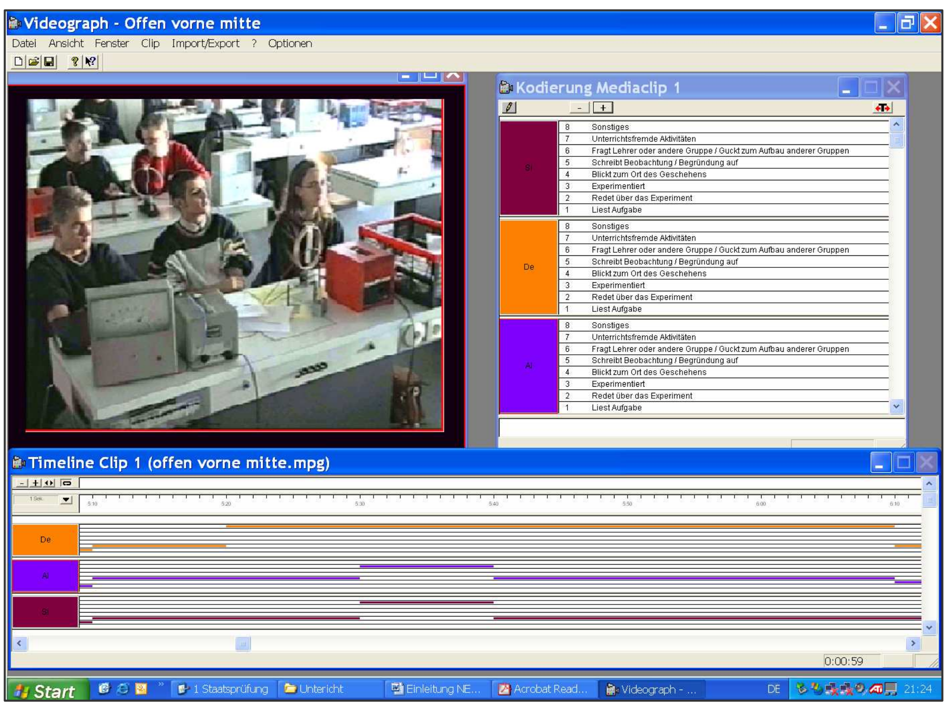

Fig 1: User interface: “videograph”

There are three windows at the user interface:
Top left → you can see the video file
Top right → action-categories
Down → time strips

In this illustration you can see the category-system for the tree pupils with 8 action-categories. Each time strip for each pupil can be coded by a mouse click with the observed action-category. The coded process data can be exported to other programmes like SPSS or EXEL, to create a set of statistics.

Results

Because of the abundance of results just a brief overview of the results can be given:

a) PHÄNOMENTA

First we take a look at the results of the examination in the PHÄNOMENTA: The following statistic shows the concentration of work, coded by category H – going into the experiment (See Tab. 1: "categories to judge work and learning habits").

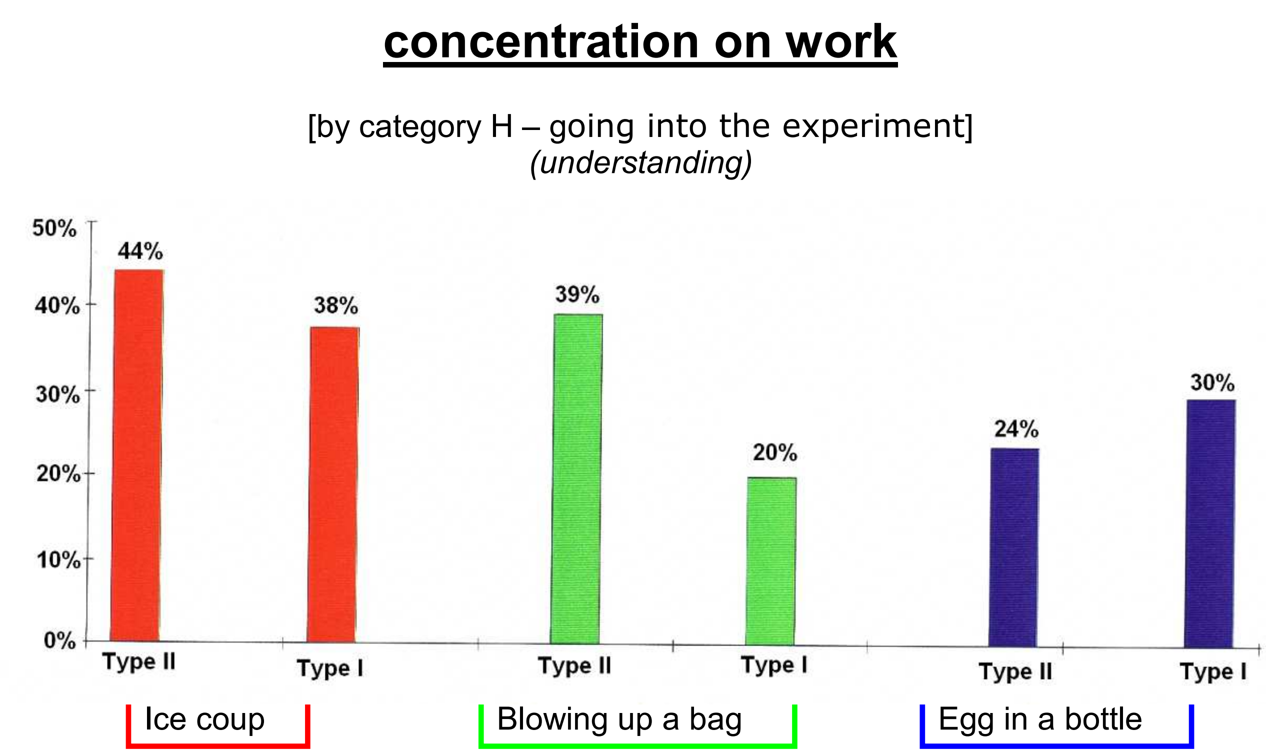

Fig. 2: concentration on work

All in all we can see that there was more intensity of work while using the less detailed formulated task (type II). Differences at the experiment "egg in a bottle" could be explained by the fact that the experiment was very demanding so the test persons had to work very concentrated although they were using the clearly defined task formulation (type I).

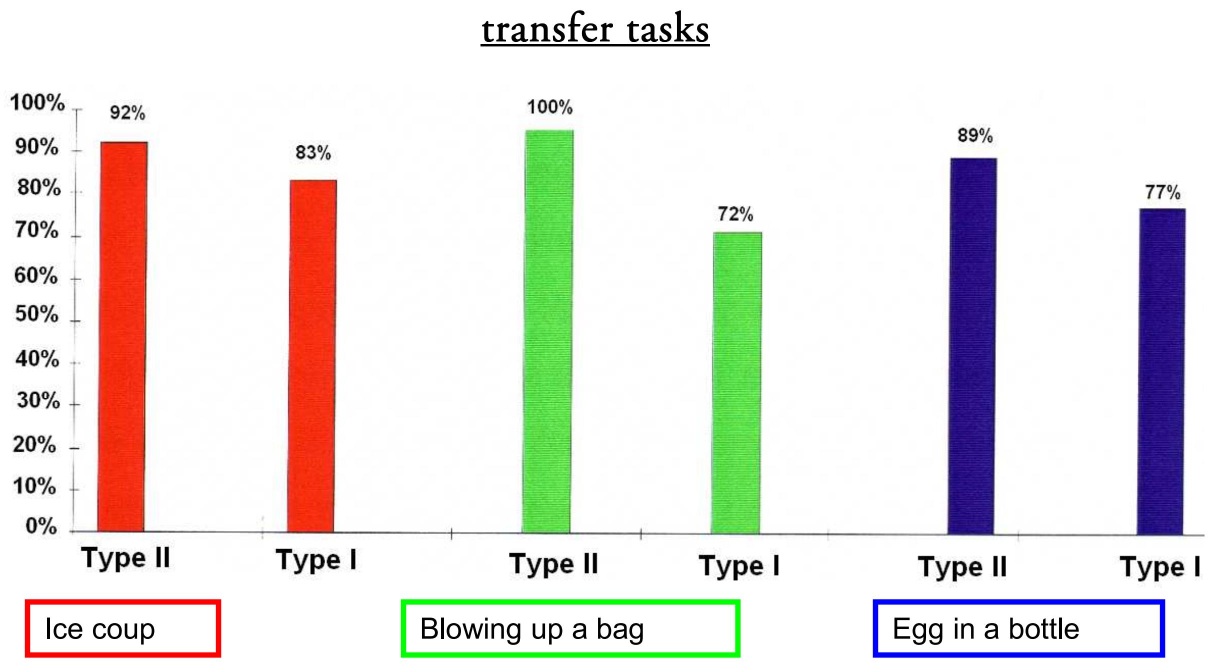

Fig. 3: Results of the transfer tasks

As we can see from the illustration 3, after working with type-II task on the whole the number of correct answered transfer tasks is 17,6 % higher than after working with type-I task formulation.

In addition, it could be shown that when examinees were confronted with Type II-formulations, they were more concentrated, were more likely to use prior knowledge to solve their tasks, reacted more positively to the tasks and were more likely to engage in discussion than when they had to solve Type-I tasks. The Type II-formulations also lead to a higher percentage of examinees solving the transfer tasks correctly.

b) Group of 8th grade students in school

If we take a look at the results of the examination in the group of pupils from 8th grade (following illustration 4) we can see that working with the type-II task leads to a higher degree of discussion, of experimenting and of observation. The shown results allow the conclusion that less detailed types of tasks stimulate examinees to work both creatively and independently. So hypothesis I can be confirmed.

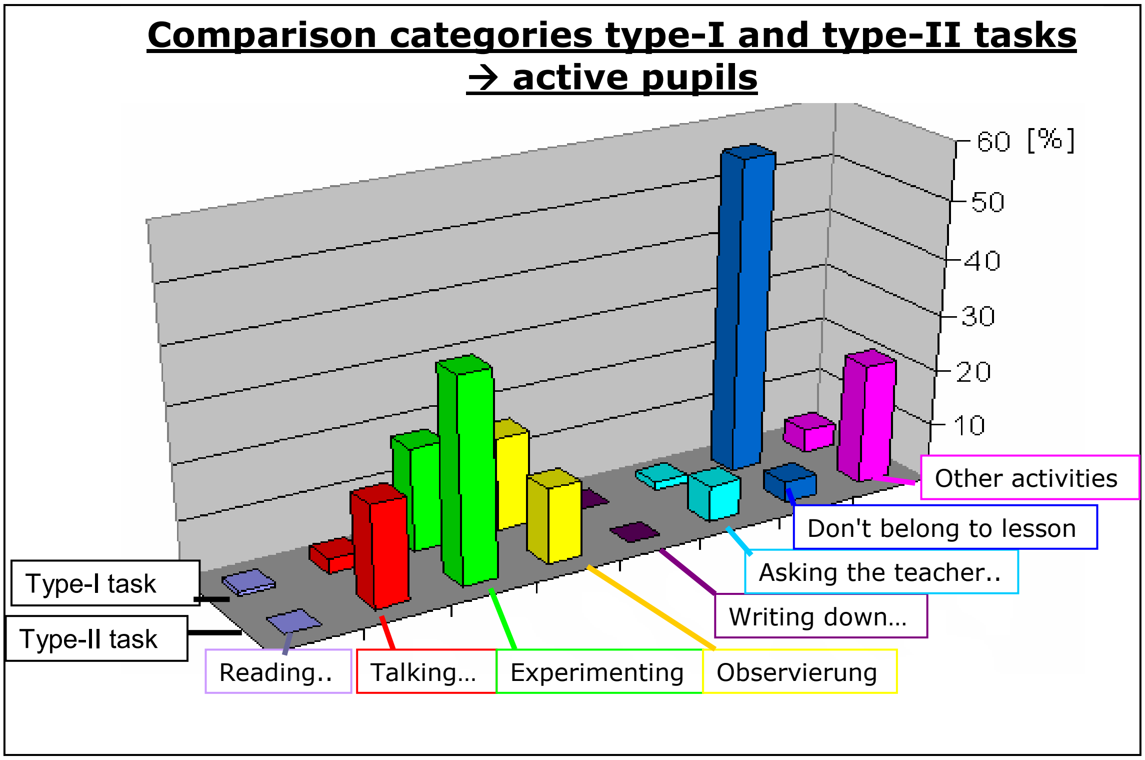

Fig. 4: Comparison categories type-I and type-II tasks

Before beginning the examination the pupils were divided according to their learning character. So it was possible to distinguish between active, sharp, success motivated pupils and quiet, reserved pupils.

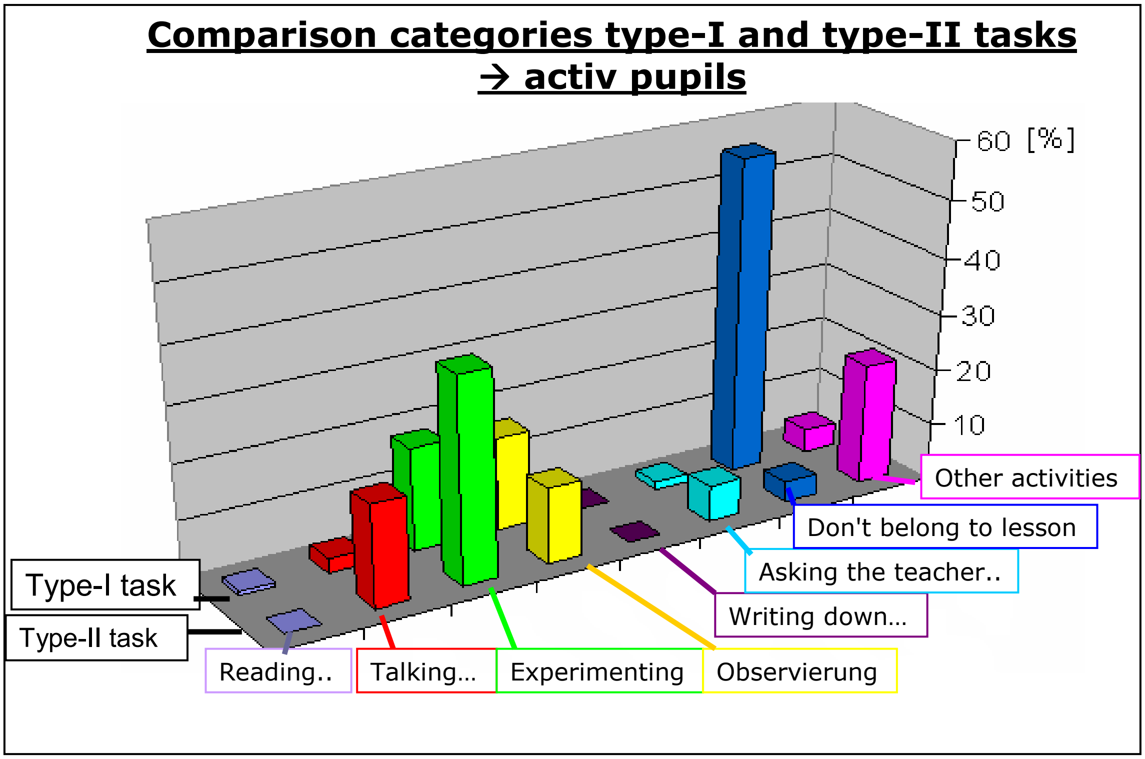

Fig. 5: Comparison categories type-I and type-II tasks → active pupils

The illustration clearly shows that active pupils using the type-I task reach a considerable higher level of the category 7 ["Activities which don't belong to the lesson"] then active pupils offered the type-II task. We can also see that sharp, success motivated pupils working with an experimental problem show a higher level of categories which allow to assume an active participation with the experiment. For example: Talking about the experiment, active experimenting, asking the teacher or other group / looking to other groups experiment and other activities.

All activities which were not recorded by the other categories but belonging to the experiment are included in the category 8 "other activities" for example: getting materials, building the experiment and cleaning up.

The results show that less detailed types of tasks stimulate examinees to work both creatively and independently. It also shows that active and very bright examinees show a more positive attitude to work when confronted with less determined test conditions.

This could only be a brief overview about the research done in a view teases at the University of Flensburg during the last year. But nevertheless the findings underline the necessity to give the pupils the chance of working at the experiments on their own way without user manuals. Evidence could be found that this special type of learning supports the children in being creative and independent individuals.

University and Science Centre collaboration in educating science communication professionals: an example from Sudbury, Ontario, Canada

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Introduction

Science communicators often say that they found their careers by accident rather than as a result of a deliberate decision. Their professionalism and mastery of science communication grew during years of practice, learning from mentors, reflecting on what works and what doesn't, and talking with peers. While the importance of communicating science effectively is widely recognized, there are very few graduate programs at universities for people with a background in science who are interested in being communicators rather than using their knowledge in a traditional scientific career. Most of the programs that have become well established, like the first in the world at the Australian National University in Canberra, Australia, have been based on a partnership with a science centre that offers opportunities for practical experience. Our program in Sudbury follows that model. However, it is broader in its theoretical scope than other programs. It might be called a "comprehensive" science communication program rather than a "specialized" program with emphasis on one or two particular media.

The program

Laurentian University and Science North began offering a 1 year Graduate Diploma in Science Communication in 2005. It as a joint venture based on a 50:50 sharing of teaching obligations. Courses are held at both the university and the science centre which are only 2 km apart. The program is administered by Co-Directors from both partners. As well as administering the program, Chantal Barriault from Science North and I brought a combination of experience that was valuable in designing and gaining support for the program. On the one hand, Ms. Barriault graduated from the Masters program in Science Communication at the University of Glamorgan, Wales, which was in partnership with Techniquest, the science centre in Cardiff, and therefore brought academic as well as nearly two decades of very varied practical experience of the field. On the other hand, I had been the founding Director of Science North for 6years in the 1980s as well as being a Professor of Earth Sciences at Laurentian with over twenty years of experience with television and radio.

Our core team is interdisciplinary, crossing faculty boundaries as well as bridging the science centre and the university. Disciplines represented comprise English, Computer Science, Earth Sciences, and Psychology.

A Diploma rather than a Masters program was chosen in order to provide students with a relatively short professionally oriented experience rather than a research oriented program involving a thesis and lasting 2 years. We speak of our graduates being able to "think like communicators" rather than having mastered all the technical skills of a particular medium such as journalism or film making. Having the science centre as a "communications laboratory" enables students to become very familiar with live audiences and free choice learning but great care is given to extracting general principles from the setting and making comparisons with other media and environments. The university recognizes the indispensable value of the practical experience contributed by the science centre and its staff without which the program would not be possible.

Mentorship and personal interaction is a high priority and enrolment is limited to 15. All students must have Honours degrees (4 years of undergraduate study), usually in science, engineering or technology although students with other degrees (for example, Philosophy and English) who have a background in science have been admitted. While most students have been recent graduates, some have come from jobs with as much as 20 years of experience, aiming for a career change or to return to their positions with expanded opportunities.

Benefits for science communication in the Science Centre

Not only is Science North the communications laboratory for the students, it is also where they interact with the centre's science staff, both formally and informally, bringing ideas from classes into conversations. The centre simultaneously becomes a learning environment for the centre's staff as they meet to discuss students' documented observations regarding audiences and effective practices. Assessment of the effectiveness of exhibits and programs has begun to move from anecdotal evidence to a more research based approach.

Senior science staff participating in the teaching and mentoring in the practical courses of module 3 gain valuable experience as they capture and translate their knowledge and years of experience into more formal insights to share with the students.

The Curriculum

The curriculum was designed to provide students with

1. a theoretical, interdisciplinary knowledge-base that enables them to analyse and understand issues relevant to science communication whatever the medium, the audience and the setting;

2. a foundation of practical experience through which they learn to communicate effectively;
3. knowledge and experience of the research that will enable them to assess the effectiveness of science communication;
4. practical experience of science communication as an intern in an organization.

The academic experience is injected with presentations and workshops offered by science communication professionals from such fields as science broadcasting, journalism, public health, and risk communication. Field trips to government science departments, research institutions and other science centres expose students to real world applications and possible future careers. An eight week internship in a science communication setting is the core of that practical experience in the workplace.

The program consists of four modules. Formal course descriptions can be found at our website sciencecommunication.ca. The short outlines that follow are informal summaries.

Module 1- September to December
Theoretical and Practical Foundations

Purpose: To provide students with the theoretical foundation for "thinking like a communicator", along with case study examples of science and society issues.

Courses:
Understanding Audiences

- Audiences engaged in free choice learning in various settings – emphasis on live programs. Also specialist and stakeholder audiences such as those involved in policy making.
- Recognition of values, beliefs, knowledge, experience, concerns, greater / lesser level of trust; feeling of inclusion / exclusion; motivation; learning abilities
- Use of reflective practice to be self-evaluative and adapt to the audience
- Observations in Science North - visitors, camps, special events

Learning: Theories and Practice

- Current theories of learning relevant to communicating science
- Growth of scientific understanding from infancy to adulthood
- Constructivist approach to learning
- Research on life-long free choice learning, adult learners and learning styles

Theories and Principles of Science Communication (Rhetoric)

- Rhetorical concepts and principles in support of effective communication; persuasion; the power of language to influence behaviour and shape values and society
- Rhetoric of science in the making and communicating of scientific knowledge
- Application of rhetorical principles to public science issues; risk communication; visual rhetoric
- Critical rhetorical analysis of public communication pieces

Science and Society

- Views on the role of public awareness / understanding of science in modern democracies
- Case studies of current issues involving public debate such as stem cells, climate change, GMOs, disposal of radioactive waste, drug testing
- Recognizing values, ethics, beliefs; framing and tone in debate
- Ways in which public participation can be effective
- "Citizen science"

Module 2 - January and February
Understanding the Development Process

Purpose: To provide students with experience in the application of first principles to the development and evaluation of science communication

Courses:
Design Theory in Science Communication

- The iterative process for designing science communication "artifacts" from capturing the scientific content to planning the user experience – especially in relation to information technology and game theory
- Well structured / ill-structured problems
- Narrative and static artifacts
- Fun and motivation
- Interaction and dynamic artifacts

Science Communication Practice

- Examples in workshop and seminar format involving the application of learning theory, audience analysis, rhetoric, design theory, understanding of science and society issues resulting in such materials as
  - Communication plans
  - Briefing notes

- Presentations by visiting professionals; field trips and meetings with science communication professionals

Research Methods in Science Communication

- Qualitative and quantitative data collection and analysis,
- Focus groups, interview methods, questionnaire design
- Grounded theory
- Experimental design
- Ethics in research with human subjects
- Coding qualitative data

Module 3 – March and April
Development Experience

Purpose:
To provide students with experience in developing science communication artifacts (materials)

Two courses from the following four:

Communicating Science through Exhibits

- Research, design, and build a prototype exhibit with signage
- Prepare a design rationale for the exhibit
- Lectures – museum and science centre exhibit research, credible and balanced content, health and safety issues, writing signage, evaluating exhibits

Communicating Science through Live Programming

- Design, develop, deliver and evaluate a show, workshop, field trip
- Lectures – designing content, presentation skills, adapting to audience response, retaining audience attention, self reflective evaluation "reflective practitioner"

Communicating Science through Information Technology

- Design, develop, evaluate a computer-based project (e.g. a simulation or visualization of a scientific principle
- Lectures – modelling of scientific concepts for simulation, how to research and design a prototype interactive interface, preparing support materials, evaluating software

Communicating Science through Mass Media

- Focus on print (magazines and newspaper) and radio; film and television depending on student interest
- Storytelling in the media
- Interview skills
- Preparation of stories and scripts from interviews with researchers and original papers in leading science journals
- Workshops with practicing professionals

Module 4 - February to June
Research Project

Purpose: To provide students with experience in defining a science communication research question, selecting a research method, conducting research and interpreting the results.

Research Project in Science Communication

Examples:

- *The Canadian public's perception of a government agency as a source of science communication: A pilot study.*
- *Exploring the public's potential perception of sustainable agriculture through communications in print mass media.*
- *What previous knowledge, experience and interest do Science North visitors have of polar science ?*
- *Learning in the Science Centre: Is there a relationship between exhibit design characteristics and visitor learning behaviours ?*
- *Framing and tone of nanotechnology in the Canadian newspaper press.*

Internship: 8 weeks from mid-April to mid-June

Purpose: To provide students with experience of communicating science in a professional context such as

- Tri-University Meson Facility, Vancouver
- Ontario Ministry of the Environment, Toronto
- Canadian Polar Commission, Ottawa
- Pollution Probe, Toronto

- Science Times, Beijing
- Experimentarium science centre, Copenhagen
- Science North, Sudbury
- Ontario Science Centre, Toronto
- Canadian Geographic magazine, Ottawa

Further information is available through the website www.sciencecommunican.ca

Enhancing formal learning in informal learning settings Considerations for teachers and guides

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Abstract

An encounter with a phenomenon in a science center exhibit can provoke many questions and discussions among the visitors. Interaction with a guide can enhance the experience and help the visitors develop a deeper understanding and see more connections to other phenomena. The outcome of the discussions depend on the visitors, but also on the guide's strategy. This paper builds on empirical material in more formal learning situations, but with relevance for interactions e.g. in a science center. We first consider formal learning outcomes based on informal learning experiences in an amusement park. We then consider tutor preparation and tutor choices, with respect to entering in the dialogue, engaging with the students and finally, ending the teaching interaction. We find that an alliance between formal and informal learning situations can be mutually beneficial.

Introduction

What strategies can a guide adopt in order to optimize visitor outcome of the interaction and involvement with an exhibit? An encounter with a phenomenon in a science center exhibit can provoke many questions and discussions among the visitors. Interaction with a guide can enhance the experience and help the visitors develop a deeper understanding and see more connections to other phenomena. In an amusement park, interaction with a guide can also help visitors discover physics or technology behind different amusement rides. The outcome of the discussions depend on the visitors, but also on the guide's strategy. The previous experience of the guide is an important factor. Still, the feedback to the guide on the effectiveness of different types of interaction is often limited, since there is, in general, no way to find out what happens in the group when they are left on their own after the interaction.

In this work, we are particularly interested in quasi-informal learning situations where e.g. a science center exhibit is visited and interacted with as a part of a formal course. How can a teacher prepare such visits?

In order to develop a model for analysing the interactions, we draw on material from more formal learning situations. In section 2 we consider a question with possible learning goals in connection with a playground or amusement park visit. The physics content concerns acceleration as a swing passes the lowest point and the question arose from a group dialogue among first year engineering students at Chalmers during their second week of term. The group dialogue was paraphrased as a problem on a written test given to a large group of students, as a way to find the different ways students would describe this situation. The results demonstrate that many students hold incompatible views without noting the conflict between the everyday and physics use of the term acceleration. The results of this analysis can be used to create tasks for group discussions in preparation for future amusement park visits for physics learning. This type of conflict can often lead to interesting group discussions, where teacher interaction may be essential to bring out more clearly the challenge inherent in the contradiction.

In section 3 we consider the situation where a teacher supervises small- group discussions as part of a larger class. As in the case for science center dialogues, the interaction time with the group is often a small part of the total time the group may be involved with the exhibit, challenge or problem at hand. In both cases the teacher or guide would like to know the thoughts, questions and difficulties of the group concerning the topic in order to optimize the interaction. The limited time available for the total interaction emphasizes the need for a strategy to elicit the thoughts of the group. Our consideration is based on video-recordings of group tutorials with limited teacher interaction. The students are studying physics during the first year of their engineering programmes at Chalmers. The video recording provides a window to analyse what happens to the discussion in the group before, during and after the teacher intervention. The results presented aim to be of direct relevance both to physics teachers and science center guides, through the focus on restricted interaction with groups around a given physical situation.

Fig. 1: A spiral rabbit and a "slinky" mounted in a swing to demonstrate forces on the rider during various parts of the ride

Considering formal learning outcomes based on informal learning experiences

A teacher may include extramural activities as part of a more formal school subject. The framing of the visit makes possible a more controlled preparation of the visit and also a more direct evaluation of the learning outcomes. In this section we focus on one aspect of the possible physics learning content from an amusement park or playground visit - the understanding of acceleration and the relation between acceleration and forces in a pendulum motion.

Light, heavy, light, heavy. During the pendulum motion in a swing, the body feels a periodic change in the forces acting on the body. In everyday life we experience the force required for acceleration in all its vector character. However, the experience of the body is rarely utilized in the teaching of mechanics. The study of the laws of motion often starts in non-motion or in uniform rectilinear motion, where the absense of net forces is counterintuitive.

What is the acceleration at the lowest point of a swing? Newton's second law relates acceleration to force, as **a=F/m**, so the acceleration is experienced throughout the accelerated body. A visual measure of the forces on the body can be obtained e.g. using a spiral toy as in Figure 1 (Pendrill and Williams, 2005). At the lowest point the swing has maximum speed. The everyday conception of acceleration as increase of speed, contrasts with the mathematical definition of acceleration as the time derivative of the velocity vector. Although the acceleration along the line of motion is zero, the maximum speed leads to a maximum in the centripetal acceleration due to the motion along the circle. However, since this acceleration is orthogonal to the motion, it involves changes only the direction of the velocity, but not the magnitude.

In a small-group discussion, one student (A) argues that, since the potential energy is lowest at the lowest point, the velocity has a maximum, and the derivative must then be zero. Another student (B) thinks that there must be something wrong with this argument, since you feel heavier than usual at the bottom. When the teacher asks if they could try to discuss the situation to resolve the contradiction, they asked if they should repeat their arguments. This dialogue was later used for an end of term quiz for first-year students, who were asked how they would help the students sort out the physics. From the replies we can identify different ways of thinking about force and acceleration in circular motion. The main categories found an analysis of the student replies are

I. The acceleration is zero
II. Referring to the centripetal force
III. Referring to the change of direction as the swing passes the lowest point
IV. Focusing on the change of angle between centripetal acceleration and the acceleration of gravity.
V. A clear distincion between the different components of the acceleration

Acceleration is zero

Some of the students' replies in the first category are undisturbed by the experience of forces at the bottom, and just express support for student A, or rephrases his claims. Other replies seem to treat force and acceleration as unrelated concepts, e.g.

- Student A is right. But the force you feel is due to the centripetal acceleration, which arises when you move in a circle.
- In the lowest position, a=0, since the swing "wants" to be there. The normal force is largest at the bottom when F_c get most "resistance" from mg.
- Student A is right. Student B is referring to the normal force.
- The acceleration is zero, but still, there is a force

The reference in the second reply to what the swing "wants" can possibly be traced to considerable amusement caused among some of the students by a similar phrase in one of the items in the Force Concept Inventory (Hestenes *et al.* 1992, Halloun *et al.* 1995) during the first day of term. The second student seems to refer to the centripetal acceleration as a non-acceleration.

Centripetal force

In the second category, most students' replies give expressions for the centripetal force and its dependence on velocity, but do no address student A's concerns, as e.g.:

- You feel heaviest at the bottom where the velocity is largest, giving the largest centripetal force, leading to a large normal force.

This is the most common type of answer.

Change of direction

In category III, students' replies more explicity discuss the change of direction of motion.

- There is absolutely an acceleration at the bottom. How else could the swing start moving upwards? It is because of the centripetal acceleration.

This respondent may recall a discussion in class about the acceleration in the highest point for a ball thrown up into the air.

Change of angle

The change in angle between the direction of the centripetal acceleration and the acceleration of gravity certainly accounts for the change in normal force from the swing acting on the rider, as referred to in replies in category IV, and would not happen in the absence of a circular motion. In the case of uniform circular motion in a vertical plane, which had been discussed in detail in class, this is the only contributing effect, whereas in a swing, the angular velocity is changing periodically and is largest at the bottom, leading to a maximum also of the centripetal acceleration, itself.

- You move along a circular track and always experience an inward force. But it feels heaviest at the lowest point because the because the centripetal force coincides with the normal force.

In this particular quote, we can also note the common confusion about directions of centripetal and/or normal forces.

Orthogonal components

Finally, some students clearly express in their replies (category V) that

- The acceleration in the lowest point is orthogonal to the velocity.

or use other ways of expressing an awareness that the different components of the motion can be treated separately.

Acceleration and force

From the replies presented above, it seems that students often fail to make the connection between force and acceleration, expressed in Newton's second law. Still most students are perfectly able to write down the law, when requested to do so. The relation between formulæ and physics deserves special attention! A stronger emphasis on the connection between force and acceleration is important to make use of the learning potential of an amusement park visit. In earlier work (Bagge and Pendrill 2003, Pendrill 2008), we have shown how 10- year olds could connect the experience of the body both to the motion of an amusement ride and to visual measurement with a slinky (as in Figure 1). Establishing this connection could thus start much earlier.

Group discussions can be one way to invite students to challenge contradicting, but coexisting points of view. However, teacher intervention can often be essential to expose or resolve the contradiction. Additional excerpts from supervised small-group discussions about acceleration can be found in Pendrill (2008). The replies from the student tests presented here give input to revise the task for student group discussions on acceleration, and also emphasized common incomplete understanding worth addressing. The next section focuses more directly on the interaction between the teacher and a group.

Considering tutor preparation and tutor choices

What happens when a teacher visits a small group discussing a puzzling exhibit or working on a physics problem? This section investigates sample dialogues, attempting to relate to what was discussed in the group before and after the teacher's visit. We present a simple model lending structure to the analysis and focusing on unearthing some major choices made, and not made, by the teacher in the particular situations. The analysis enables us to draw some conclusions on how to prepare for tutoring situations and how to handle them in practice in such a way as to support the learning outcome.

A common feature of physics courses is that students work on various problems, often in small groups tutored by teachers. At our physics department the forms of the group work are relatively free. Students are free to form and reform groups, work in the presence of other groups or separately. The content is set by a list of problems, and no particular form for the group interaction is imposed on the students, and the students receive no particular training in how to work in groups. From a small informal survey among some of the teachers at the department it is clear that typical preparation mainly consists of different kinds of consideration of the conceptual and mathematical difficulties of the problems set for the students – sometimes restricted to 'solving' the problems. From our personal experience of teaching at various physics departments, this situation is not uncommon.

Ideas for interaction are mainly drawn from personal experience, partially from discussions from colleagues and sometimes from literature such as Jacques (2000). However, it is scarce to find less generic literature which gives opportunities for reflection in relation to the teachers' practice and which is suitable to draw on with respect to how to facilitate students' learning of the physics content and to spot and address conceptual difficulties in the groups you encounter – in short literature supportive in developing good practice. Most literature is concerned with investigating cooperative learning, more stable groups, favourable mixing, size and physical arrangements, and looking for achievement differences (see e.g. Springer et al, 1999, and Bennet et al, 2004, for overviews). In connection with informal learning, the dialogues within family groups have been investigated e.g. by Ash (2003). These issues are discussed also in connection with the presentation of Context- Rich problems in physics. (for example, see Heller and Hollabaugh, 1992, Heller et al 1992, and Waltner et al 2007)

The empirical data consists of video and audio recordings of groups of three or four, while they were working with two mechanics problems. During the hour they had at their disposal, a teacher visited them two times each, on average for five minutes. The students were first year university students in a MSc program on biotechnology at Chalmers University of Technology, taking a service course in mechanics (almost identical to the course given to students majoring in physics). The students were volunteers from the full class of 35 students, and for the duration of the hour they were in separate rooms, while the students not participating in the study worked in groups in their normal classroom with the same problems, also tutored on the same level. At the time, lecturing on non-accelerated mechanics had just come to a close, and these problems were the last of this kind ‘officially’ considered in class with tutoring. The first of these problems presented the students with the situation of an ox dragging a box. They were asked what forces acted in the situation. Then, they were asked how the forces would be affected if the mass of the box doubled and if the mass of the ox was doubled. The second problem concerned the best choice of angle for a string used to drag a board over rough ground.

Having transcripts of the students’ conversation readily available, we closely followed the supervisory episodes, as well as a few minutes running up to and following the episode where the teacher was present. Initial discussions resulted in a simple model of the episodes, which was used to systematically structure observations in the whole of the material.

Tutor interaction analysis

Having transcripts of the students' conversation readily available, we closely followed the supervisory episodes, as well as a few minutes running up to and following the episode where the teacher was present. Initial discussions resulted in a simple model of the episodes, which was used to systematically structure observations in the whole of the material.

The model we use to structure our analysis of the tutoring episodes can be described by four questions:

1. What happens when the teacher enters? What is the effect on the students' discussion and how does the teacher inform herself on the students' conceptual context?
2. What does the teacher chose to thematise, and on what level, in the main part of the interaction?
3. What characterises the interaction?
4. How is the episode brought to a closure, and what potential does it offer to the students?

By answering these questions for each of our episodes we enable a discussion on alternative paths available to the teacher, which can be considered in practice. By answering these questions for each of our episodes we enable a discussion on alternative paths available to the teacher, which can be considered in practice.

Here we will limit ourselves to consider one episode in part to show some basics of our analysis. In the extract below the students H, I, J, K have been working with the first problem about five minutes, and the teacher (T) enters. The minute before the students have been discussing whether friction (unclear what friction) is the 'driving' force that makes the whole thing move. They are certain there must be a force directed forward, which is larger than the friction on the box when moving at constant velocity.

1. All including T hello [nervous laughter from students]
2. K well, I don't know
3. I this is when one realises how little you know about these things
4. T It looks innocently simple, doesn't it?
5. All yeah, [murmuring]
6. K yeah, we know that there must be a force that it [the ox] affects the box with, ok?
7. H the forces in the rope should be equal
8. I equal
9. H equal in both directions
10. I equal in both directions, yes, but the driving force, wouldn't that be that the ox has larger friction than the box? [3 second pause, T looks troubled]
11. H,I no [Laughter from all including T]
12. T Perhaps you are getting close, somewhere there
13. I We don't want to be close, we want to
14. K ok, we have a...
15. T if we start with the rope, why are the forces equal in the different directions. You do not always discuss, but just claim, have you thought about it?

Looking at this extract, in lines 1-5, the students' discussion is interrupted when the teacher enters, giving small opportunities to listen in on how they have approached the problem. In line 6- 10, the students are asking two main questions to the teacher for affirmation: Are the forces in the rope equal in both directions, are the driving force the friction on the ox?

We can observe several conceptual problems such as where force balance is requested (in the rope, on the ox etc), whether the forces should be equal for constant velocity or there should be a driving force, and what system is considered (the ox and box together, separately, or something else). When the teacher does not confirm the student question (end of line 10), the hint is taken (line 11). The teacher then makes a decision on how to proceed, and on line 15 starts thematising the force balance in the rope on a quite detailed level, similar to a short interactive lecture. She unconsciously chooses to ignore the other possibilities of addressing conceptual problems that was displayed in the student conversation. Further down the line, when the teacher no longer is present, the students initially fail to see the connection between force balance in the rope and force balance in the whole system of ox, box and rope. Only after considerable discussion (approximately 10 minutes), the group starts to recognise what force balance requires in the present problem (that the sum of all forces external to the system should equal zero for constant velocity).

Conclusion

Group discussions are influenced by participants previous perception of the problem, which are not always discussed explicitly. In general, the teacher or guide, has one (or more) optimal outcomes of the discussion, which may be more or less conscious. Many different obstacles or impediments may obstruct the intented learning outcome of an exhibit or a problem. A conceptual problem discovered in an informal learning situation can give input to formal teaching. At the same time the formal learning situation offers possibilities of more detailed studies in controlled situations. Analysis of recorded discussions can be helpful, e.g. for the development of strategies to elicit ways of thinking about the exhibit or problem at hand. We point to our questions as guiding points for the reflection of teachers and guides: How can you enter the interaction?, how can you engage the students or visitors? and finally, how do you end the interaction? An essential question is how to be well prepared to meet these situations. This paper aim to give some tools for the prepration to handle choices in relations to these situations. From the analyses in this work we conclude that

- Access to empirical material of the kind presented here is valuable in seeing opportunities for the actions of teachers and guides.
- Essential for facilitating student learning is to discern student conceptual difficulties and it is an advantage to consciously consider alternative actions.
- It is important as a teacher to be informed on common conceptual difficulties on the particular topic taught, e.g. from colleagues, systematic reflection, and literature.

An alliance between formal and informal learning situations can be mutually beneficial.

Acknowledgements

This work has benefited from interesting discussions with our colleague Tom Adawi concerning the Ox and box problem. We also express our appreciation to the students who participated and to Maria Berge and Ann-Sofie Axelsson who played an essential role in recording and preparing the video material that we analysed. Partial financial support for this project has been provided by the Committee for Educational Science of the Swedish Research Council (VR-UVK), and also by the Chalmers Strategic Effort in Learning and Teaching (CSELT).

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PhänoLab - Chemistry for children aged 8-12

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Intentions of the project "PhänoLab"

The simple experiments of the PhänoLab shall enable children to have their first experiences with chemistry. Observations show that very simple tasks - as measurements of liquids or the lighting of a match - are real challenges for children at this age.

The instructions are supposed to be a stimulus and shall encourage the children to work on their own. Children are used to getting the possible solution in advance by the teacher. The common question is the following one: "What do you want me to do now?" The experiments of the PhänoLab are supposed to oppose these consumer habits and give children confidence to create their own ideas.

The experiments are constructed as interactive experiments. The interaction between child and child is the most important fact. Human interaction results in satisfaction. The children shall also interact with the subjects or objects on the table witch belong to the experiment. In the discussion the children shall also change the performing of the experiment. The children are supposed to work with the interactive experiments considering the following points

- Working with instructions
- Repeating and transforming the experiments to get better results
- Getting first hypothesis for the reason why it works
- Explaining the results with children's words without formulars and chemical terms

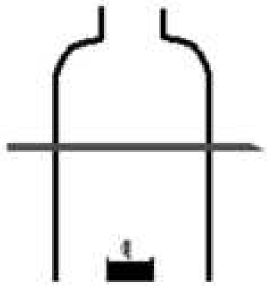
Examples for the experiments

Experiments for the topic "fire" have been developed in cooperation with the fire brigade Flensburg and different courses at the University of Flensburg. These are six different experiments which are installed at the same time and are dealt with in groups.

To save the results of experiments booklets with pictures are issued which contain questions to the experiments in different levels of difficulty. When the children work with the booklets it is possible that the teacher asks additional questions to improve the comprehension of the experiment or the group of experiments.

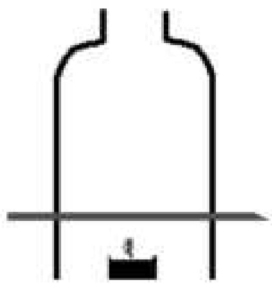
The following picture shows the configuration of instructions:

Is heat alone enough to light a fire?



Put a wooden stick through the two highest holes of the bottle
Lighten the tea warmer candle

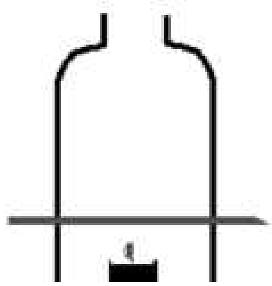
Put the bottle over the candle, wait and watch



Pull the wooden stick out of the bottle and use the next two lower holes

Lighten the tea warmer candle

Put the bottle over the candle, wait and watch



Put the wooden stick deeper from hole to hole and wait if something happens

The stick must not touch the flame

The instructions are supported by pictures. This configuration makes it easier for the children to understand what they are supposed to do.
The demand on formal chemical ways of explanation is very small. The words of children in explaining the experiment are valid.

The experiments were tested at the “Phänomenta“ in Flensburg and in schools. High demands were placed on the behaviour of the students from the University or teachers. The children should feel free in their activities but get help when they have questions.

Results

Observations with prepared worksheets help to analyze the quality of the experiments. The observers pay attention to the children´s behaviour in the laboratories. The categories of observation are:

Level I: Attention

- observes, starts the experiment, first activities

"oberserves" means that the child looks at the things on the table

Level II: Perception

- asks questions. repeats parts of the experiment

"asks questions" means that the child talks with the other members of the working group

Level III: Comprehension

- works intensively, tests different ways of doing the experiment, tries to get further information

"working intensively" means that the children work for about an hour without doing anything else.
"further information" means, that the child asks the teacher.

At this time only a description will do. It's no good giving chemical formula at this time
The teacher or the student who comes to school with the experiments has nothing else to do than to observe the children.

The children have very different results when they work with the experiments. Some pupils only reach level one, especially when they have other difficulties in their schoollife. But the experiment is only good when other groups of the class also reach level II or level III

Results of the observations of good experiments

- astonishment
- the children need time: observation, changing, trying out the experiment, repeating, showing it to the others
- discussing the experiments
- working intensively

The results show that the children work intensively and that they are extremely emotionally engaged. Most of the children reach a high level in their observations and explanations.

Basic science-education in Kindergarten

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Introduction

Preschool Scientific education – should subjects like physics and chemistry already be implemented into the kindergarten environment? Fears and hopes do accompany this lively discussion, which seems to gain significant importance! One knows about the great interest of children in an preschool age in scientific phenomenons and explanations. Television programmes like the educational format ‚Die Sendung mit der Maus' experience increasing audience ratings and rising popularity.

However the academic exploration of the topic of preschool scientific education has been a rather recent development in Germany. The apparent discrepancy of science education among kindergarten aged children is based on *Piaget's* conclusion that the ability of reasoning and logical thought is first developed from the age of twelf. This however, is seen as the postulate of scientific understanding. Consequential physics and chemistry are beginning very late in school, when the scholars are 12 years old. New studies in the field of developmental psychology suggest though, that children acquire the ability of logical thinking much earlier. In addition a number of arguments could be used to emphasise the importance of preschool science education: Preschool children are in a phase of their development, in which an enthusiastic approach towards science can be sustainably shaped. The excitement for natural phenomenons within this age group is described as a ‚window of time' for an imprint of interest. Further support for an earlier educational approach can be found from the field of education policy, which sees it as a necessary consequence of the results of the ‚PISA' research study, but also the economic system is worried about the lack of procreation of scientific experts.

Learning in Science Centers and Kindergarten

The first question that comes to mind is: How is this topic field connected to the Science centers? In my doctoral dissertation (Schließmann, 2005) I focused on the "informal learning" processes on interactive experiments in science centers. If you compare the results of my study with the demands on the early scientific education of children in an preschool age one notices significant congruence. The approach of interactive exhibits allows an individual approach of children towards the world they are living in through personal and ‚real' experiences. The guidelines for kindergartens postulate a concept where can implemented self-education. Due to it we felt that interactive stations are the adequate approach. The following questions as guidelines

- What conditions have to be given in order for children to develop there own questions and find, by themselves, the answers to them?
- What ist he specific role of kindergarten teachers within this process?
- Which experimental stations are suited for preschool aged children and
- how can we record the potential educational success?
- How can an idea be put sustainable into action?

Scientific Education in Kindergarten

The first thing that was of importance for us was that the people in direct contact with the children, the people that work with them become convinced and enthused with the project.
For that reason we lay the focus of our concept on the kindergarten teachers and hence created natural science workshops. The aims of this workshops are:

- Introduction to work with interactive exhibits and pedagogic conceptual design
- Reflexion of the own attitude, relive aversion to sciences
- Implementation of the pedagogic conceptual design to practical experience
- Handling problems in experimentating with children
- Construction of exhibits

After each session the participants will try out their gained knowledge in their workplace. The experience will then be discussed in the next session. After the end of the workshop the participants are able in a professional ability to work with children in kindergartens on natural science topics.

The training workshops are divided into four main sessions. The first three are topical orientated, in which experience with the experimental stations is gained. In every session the participants engage into a so called "genetic conversation" in which they are asked to find answers to the experiments. The last and fourth session mainly introduces the practical construction skills in order to build the experimental stations, which they are allowed to take with them, in the Kitas.

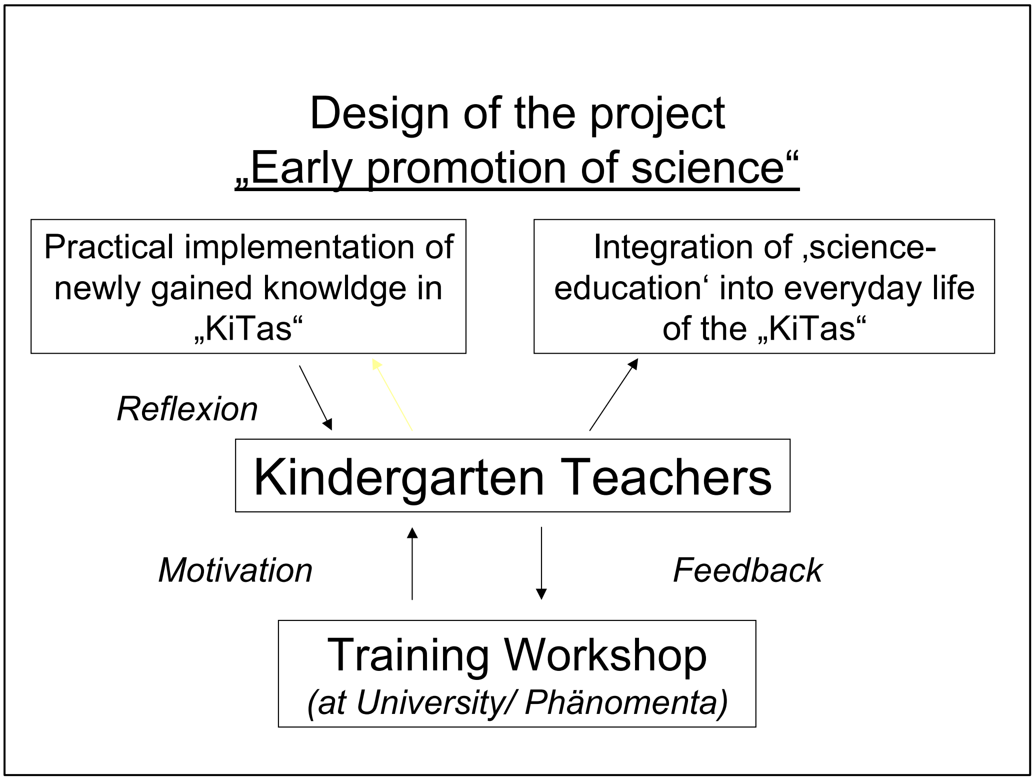

Fig. 1: Design of the Project

Evaluation of the Project

Our institute has the duty to record the effectiveness of this project. Thereby we consider the following questions:

- Investigation: „Does the training workshop effect the curriculum of kindergartens?“
- Problem formulation*:*
- Are the exhibits used at regular intervals?
- Does the attitude of the preschool teachers in „promoting early sciences“ change?
- Do the exhibits become part and parcel of the curriculum?

How are the workers handling problems in coaching the children?

In the beginning of the study the personal attitudes of the kindergarten teachers in the following areas are questioned:

- Motivation
- Self-concept
- Didactic skills
- Effort to work hard, exercise patience

- Interest in science & early promotion of it.

The special focus of the project always lays on the learning results of the children on the experimental stations. In the first step we had to concentrate on the development and proving of suitable interactive exhibits, which could fulfill the criteria of suitable interactive experimental stations, so a self-navigated and informal learning process is possible. We found that the ‚walkable bridge' offered the ideal criteria. On this station we could monitor the behaviour of children at the exhibits through a video-study. The analysis and categorization of results was then done in the program ‚Videograph'.

Fig. 2: "The Walkable Bridge"

The children receive a basic construct on which the endpieces of the bridge are tightly assembled. Then the children build the rest of the bridge (the middle part) out of seven remaining, different shaped bridge-pieces, whereas the pieces have to be *assabled* in a certain arrangement in order to probably built it. This ‚preliminary investigation' shows the observation results of the behavioural patterns ("Depth of Learning" (Barriault, 1999)) of children on the ‚walkable bridge' station. The observations of behavioural patterns are presented here in a "depth of learning" visual.

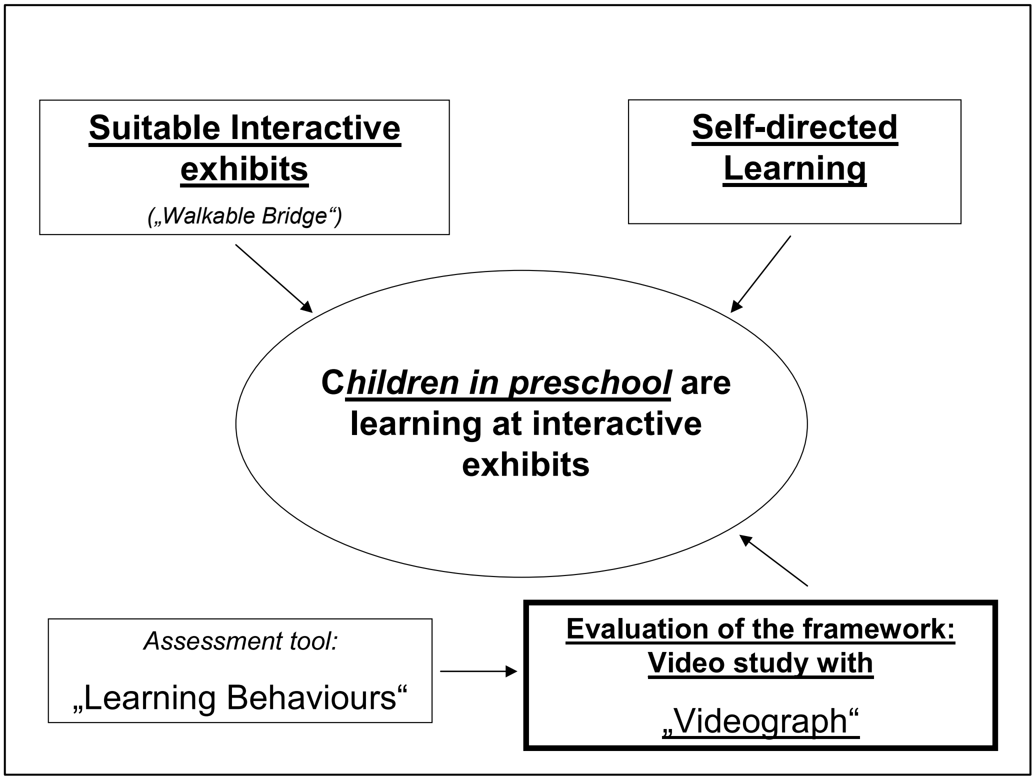

Fig. 3: Design of Investigation

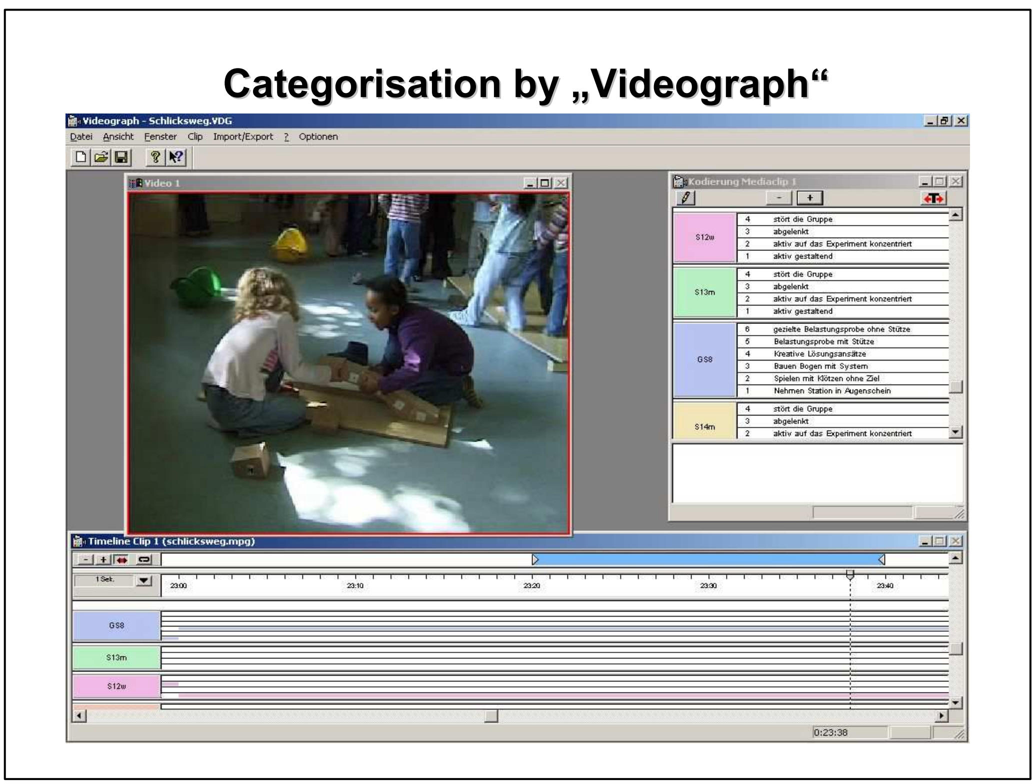

Fig. 4: Screen "Videograph"

The programm „Videograph“ allows a category-based investigation of the observed behaviours. The categories are defined in schema Abb.5. This method of ‚learning behaviours’ has been used and been further enhanced during the analysis of the children approaches towards experimental stations in the Phaenomenta.

My work (Schließmann 2005; 2006a) also established this method among the academic field of didactics and natural science in Germany. It was noticed that for the analysis, documentation and categorization the technique of video study was the most suitable. In my study I have as a starting point listed the essential behavioural patterns of children during the building process of the bridge and have then have allocated them to their level of ‚depth of learning’.

Categories of Operation assigned to „Depth of Learning“

Categories of Operation	***Depth of Learning***
Creative solutions in constructing the bridge ***C 3.2.*** Load test without brace support ***C 3.1.***	**Category 3** *„Breakthrough Behaviours“* „Flow“
Load test with brace support ***C 2.2.*** Constructing the bridge arch ***C 2.1.***	**Category 2** *„Transition Behaviours“*
Look closely at the exhibit ***C 1.3.*** Playing with the components ***C 1.2.*** Watching others engaging in the acitvity ***C 1.1.***	**Category 1** *„Initiation Behaviours“*
Turn away from exhibit ***C 0.2.*** Leaving the experiment after a short time ***C 0.1.***	**Category 0** Negative Reactions

Fig. 5: Classification "Depth of Learning"

Results

As you can see in the diagram there is a very small percentage of negative reactions, sixty-four percent were categorized within the high categories two and three. A study of *Rogge* shows, that the negative reactions in experimental education in physics were twice as much negative reactions.

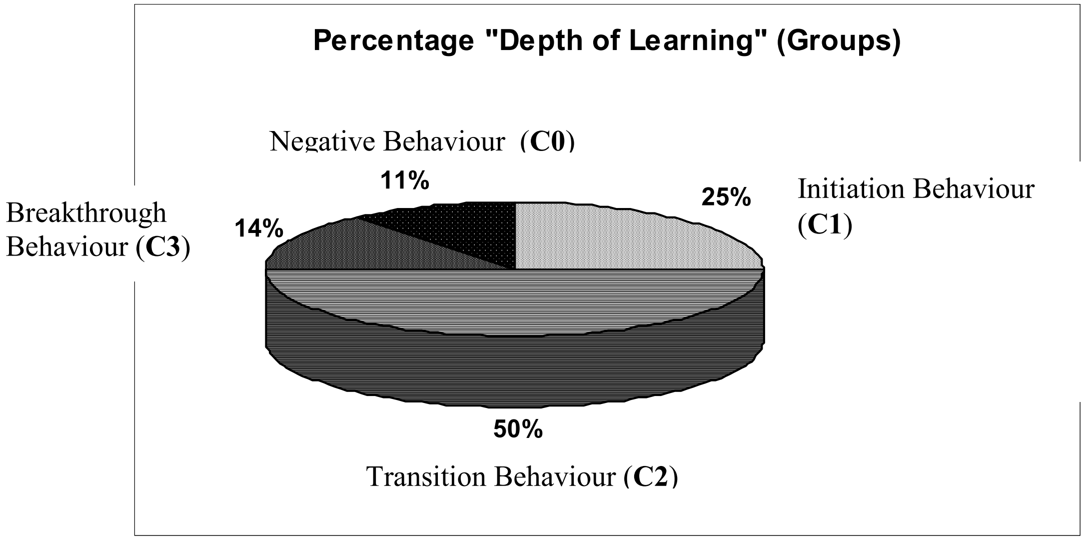

Fig. 6: Results investigation "Depth of Learning"

Now I'd like to give you an overview over the essential behavioural patterns observed at the ‚walkable bridge' and their classification into the categories of depth of learning.

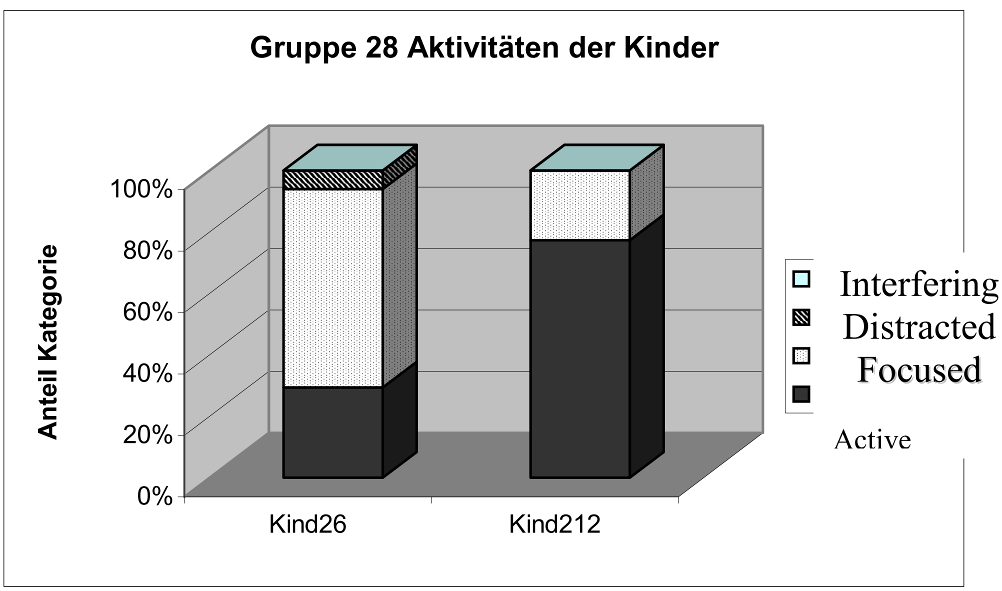

Fig. 7: Acivity of two children

The degree of concentration with which the children worked on the station is shown in this graphs. It could often be seen that one children took a leading role in the process - however the children are still engaged in team work. More results in (Schließmann, 2006b; 2006c).

Conclusion

The observation made in this study suggest the following results:

- the project seems to be able to achieve educational results among the group of preschool children and initiate a sustainable interest in natural science
- The informal learning at the interactive exhibits is appropriate to the hands-on explorative approach of the children to recognize the world
- The workshops were able to motivate and enthuse kindergarten teachers to work and experiment with natural science projects together with the children.
- the method of video study and the categorization into the different levels of "depth of learning" act as an essential basis for further studies about informal and interest navigated learning in kindergarten.

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What Children Think - The Anticipation of Scientists about Children's Understanding of the Nature of Science

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Abstract

Science Communication is a key issue of rapidly growing science complexity. Research institutes and other public institutions are open-minded to offer insights into contents and methods of scientific work - especially to children, because they should become well-informed adults and the next researchers´ generation. Out-of-school learning environments like museums, science centres or special students´ laboratories at research institutes or universities have the possibility to enhance the interest for science. These informal learning settings share the education not only of scientific contents but also of aspects about the research work and methods. This presented study focus on face-to-face-communication in out-of-school learning environments. Scientists want to inform students how science works. Therefore they have to anticipate their communication partners´ levels of knowledge and adapt their own communication to the target groups, particularly when talking to younger students. Can scientists take the perspective of their audience? In order to testify scientists´ potential to anticipate 10 to 12 year old students´ knowledge about aspects of the Nature of Science, this study will give a definition of students´ knowledge first. Following steps to a development of methods and instruments to compare children´ s knowledge with the anticipation of scientists considering this knowledge are shown.

Introduction

What is the origin of scientific knowledge? How do scientists gain new insights? What is an experiment, and what do research processes look like?

The Nature of Science is an important issue in science communication. To anticipate its understanding among the target group plays a key role in face-to-face communication. Scientists in out-of-school learning environments should know their audience's level of knowledge very well when talking about science, using scientific terms, describing research work and methods. Is there a common ground in the communication about the nature of science between the expert scientist and the student as the layperson? Can scientists correctly anticipate the knowledge of 10 to 12 year old students?

We need to investigate the layperson's actual knowledge about aspects of the Nature of Science to compare it to the expert's anticipation.

The aim of this study is at first to develop a method and an instrument in order to be able to gather partial aspects of students' understanding of the Nature of Science like scientific reasoning and methods. Secondly, this study wants to define the experts´ anticipation concerning the students´ knowledge.

Theoretical background

Science Communication

Since the late 1990s the German scientific community has an ambition to enhance the communication between science and public (Deutscher Stifterverband 1999). This lead e.g. to the programs PUSH (Public Understanding of Science and Humanities) and afterwards PUR (Public Understanding of Research), aiming to inform the broad public about the latest scientific questions, issues, works and methods. Subsequently, research institutes and public institutions like museums or science centres initiated a lot of projects - in many cases intended for students - to enhance the interest in science. Informal learning settings like exhibitions with hands-on character or laboratories were arranged where students can perform experiments and experience how science works.

In these out-of-school learning environments science education and science communication take place. By talking to scientists who are involved in these informal learning arrangements students get to know not only scientific topics and results- but also aspects of scientific methods and reasoning. For this face-to-face communication a common ground, i.e. an overlap of knowledge between the communication partners, is necessary (Clark 1991). Bromme found a definition for a communication between an expert and a layperson, which is characterised by different levels of knowledge (Bromme 2000; Bromme and Jucks 2003). The expert is specialised in knowledge based on his professional education and experiences. The layperson does not have such professional knowledge, but does have previous knowledge and special point of views and experiences. When talking to a layperson about specific issues the expert has to estimate the recipients´ pre-existing knowledge. Taking the perspective of another person who does not have the same knowledge level is a very important aspect in expert-layperson-communication. Experts often overestimate the layperson's knowledge because of two reasons: Firstly, they assume their level of knowledge as comparable with others not recognizing that their own knowledge is elaborated and specialised, based on a long education (so called correspondence hypothesis); and secondly they overrate the commonality of their own knowledge (overestimating hypothesis, Bromme 2001).

The term „Understanding the Nature of Science"

'Scientific Literacy', 'Public Understanding of Science' (PUS), 'La Culture Scientifique"'or 'Naturwissenschaftliche Grundbildung' sum up what the general public should know about sciences (Durant, 1993). The PISA foci on 'Basic Science Education' refer to the knowledge of scientific methods (scientific reasoning), the aims (scientific explanations), and the essence of science and technology as well as its position in society. An important aspect of this basic education is the Nature of Science (NOS, Pella, 1966) as understanding laws and methods of sciences (Millar & Wynne, 1988). Scientific issues and results as well as the Nature of Science, i.e. the knowledge of scientific processes and methods, plays a very important role in science education (Driver 1996; Baumert 2001).

At the start of the 20th century John Dewey (1910), called for considering scientific methods when teaching science, not just scientific contents alone. In addition understanding the Nature of Science (NOS) is just as much a part of basic science education as the knowledge of concrete subject results (Bybee, 2003). The understanding how science works can help to learn about scientific contents (Grygier et al, 2002). Knowledge of research processes and methods contributes significantly to successful science learning (Baumert et al., 2001; Driver, 1996).

The term, 'Understanding the Nature of Science', comprises a multitude of definitions, which, first of all, will be narrowed down here. Beate Sodian, the psychologist, describes 'Understanding the Nature of Science' as an insight into the epistemological fundamentals for scientific ethics of the sciences (Sodian et al., 2002). In Anglo-American society, these aspects have been an integral part of science education for many decades now, whereas in Germany they still tend to play a subordinate role. Individual areas, such as the model terminus or the methods of sciences are mainly touched on at upper secondary level, but very seldom, however, in the middle school or in the primary school (Grygier et al., 2004).

McComas (1998) describes science as a part of the cultural and social tradition. The produced knowledge is always susceptible to change and cumulation. Science is an attempt to explain natural phenomena and to construct models of the world as they are portrayed to us. A scientist requires, among other things, a sceptical and creative frame of mind. Knowledge acquisition is part of the epistemological aspects of science. Mayer (Mayer et al., 2003) refers to three dimensions of knowledge acquisition: Practical work techniques, scientific epistemological

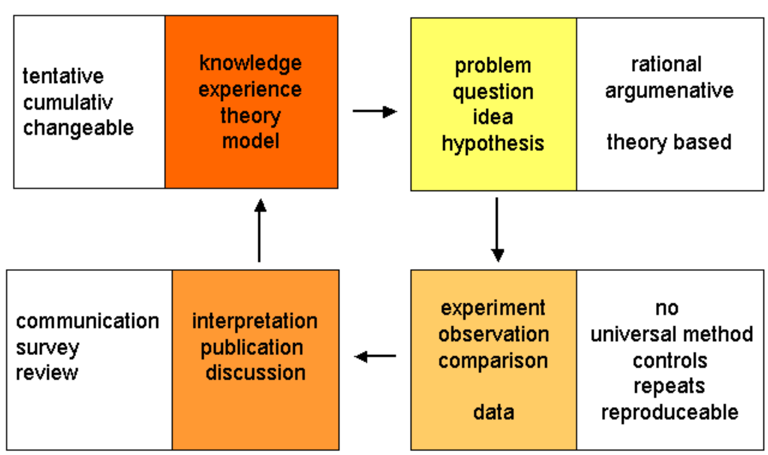

Fig. 1: Schematic and simplified picture of scientific processes (Carey & Smith, 1993; Duit et al., 2004; Hammann, 2004; McComas, 2005)

methods and characteristics of the sciences. His epistemological methods refer to scientific methods such as formulating hypotheses, planning and carrying out examinations.

Even though considerable differences exist between the different subjects as well as within the individual subject disciplines; a common structure of scientific thinking and working exists, which we will deal with here in more detail. The cyclic research process is characterised by different processes, which have been simply described in figure 1. The scientific process is cyclic and tentative. The hypothesis, generated through a problem or a question should be rational in argumentation and theory based. Although there is no universal method, an experiment or an observation should be controlled and verified through repetition. Data should be reproducible. The results are published and reviewed by the scientific community. The scientific knowledge is cumulative and changeable.

Students´ Understanding of the Nature of Science

In science didactics, the impartation of scientific methods is allotted an important role to support 'Understanding of the Nature of Science' as well as within the learning processes. Students, who have understood fundamental processes find it easier to understand scientific contents and results (Baumert et al., 2001; Driver, 1996).

According to psychological studies, young students frequently view the research process less differentiated (Grygier et al., 2002; Sodian et al., 2002). Generally, they regard scientific work as pure activity, detached from the underlying idea. They do not recognise coherences and aims. The experiment stands isolated and is not embedded in a theory – evidence – context. Gathering facts or discovering remedies are the main aims pertaining to the environment. Scientists can easily decipher information or make discoveries (Carey, 1989; Smith et al., 2000): this process has been described as naïve realism (Thoermer & Sodian, 2002). An additional term for perceiving science is the so-called engineers´ knowledge perception': fundamental processes and laws are non-important; the issue is: does something function or doesn't it?. Normally, children have little understanding for the cyclical processes described in figure 1 including the rationality and processes involved here (Aikenhead, 1987; Lederman et al., 1998).

Contrary to Piaget's opinion that children can only develop rational faculties between the ages of 13 and 15 which allow them to formulate a hypothesis and examine it, new studies, however, show that prerequisites for the main features of epistemological reflections can already be established among children attending third class (Leach, 1999; Mayer et al., 2007; Samarapungavan, 1992).

Concept frame, research questions and hypothesis

In the framework of a PhD on science communication in out-of-school learning environments, we need to investigate the layperson's actual understanding of the Nature of Science to compare it to the expert's estimation. First of all children's knowledge is to be determined by using a questionnaire. For this reason, categories of different understanding levels had to be developed which divides the students´ statements.

Research questions:

1. How does children's understanding of aspects of Nature of Science in the age of 10 to 12 years look like?
2. How do scientists anticipate children's understanding of these aspects of Nature of Science?

Research hypotheses:

1. Children's understanding of aspects of Nature of Science is on a base level.

a. According to students, science does not have a clear direction.

b. Science is regarded more as pure action rather than a data collection.

c. Students see no connection between hypothesis, experiment and data

2. The Scientists overestimate the children's understanding of aspects of the Nature of Science

a. The estimations of scientists are connected with their experiences.

Methods and samples

Research design

To assess the understanding of the Nature of Science of 10 to 12 year- old students a questionnaire was developed on the basis of the NOS-Interviews (Carey 1989; Smith et al. 2000; Grygier et al. 2002; Sodian et al. 2002; Thoermer and Sodian 2002) using an open answer format. The items comprise questions about the goal of science, the everyday life of a scientist and scientific problems with particular emphasis on the development on scientific ideas. Other items on the one hand addressed the relationship between ideas and experiments and on the other hand the relationship between data and evaluation of ideas. After testing the questionnaire, it was reviewed and finally given to the sample. Grades of knowledge to classify students´ statements were established based on the literature (Carey 1989; Smith et al. 2000; Grygier et al. 2002; Sodian et al. 2002; Thoermer and Sodian 2002).

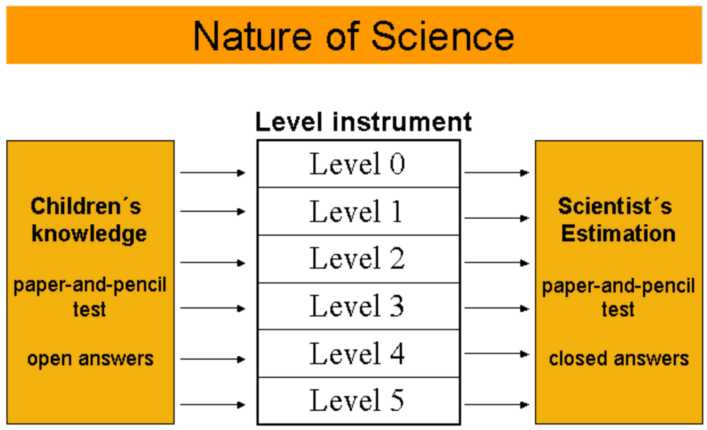

Fig. 2: Research Design

Subsequently, an instrument to test the scientist's skills to estimate the students´ knowledge about the nature of science will be constructed. Therefore a second questionnaire with the graded statements of the children in a multiple-choice format will be developed and given to scientists who work in out-of-school learning environments. They will have to rate the statements of the children. Two comparisons are intended: the estimation of the scientists with the actual state of the students' understanding and the experts´ experience and qualification compared with their estimations regarding to the children's knowledge.

Questionnaire method to determine children's understanding of aspects of the Nature of Science in the age of 10 to 12

The method of the Nature of Science interviews on how to assess an understanding of science was adapted to the questionnaire method with an open answer format. Nine different items on metatheoretical aspects of science as well as scientific methods and processes were developed. They are summarized in the following sub-areas:

1. Aim of the sciences

   The objective of this question is to establish if students can classify what science is and what it does. Are the students in the position to see science as an attempt to explain phenomena also as a construction of knowledge?
2. Genesis of knowledge

   This question is about students´ understanding of science as an activity or a collection of facts. It differentiates students with naive realism, regarding science as something stationary or students who see the cyclical-cumulative character of science.
3. Ideas and deducing questions

What originates from a question and an idea which illustrates the simple description of a hypothesis here? Can children describe the theory-deduced character of scientific work and then combine ideas, experiments and evidence into a meaningful context?

4. Research process: Experiment [Relation Idea – Experiment]
   This question deals with partial steps of the research process, which focus on the experiment. Can the students classify the experiment in the course of the research process? Do students see the sense of an experiment more in causing an effect or recognizing that the experiment is epistemological and that it serves the purpose of examining ideas?
5. Research process and evaluation of ideas [Relation Results – Idea]
   Are students in the position to coordinate questions, ideas and findings meaningfully? Can they describe the process which shows that experiments result in findings that either verify or negate ideas so that they have to be rejected or revised?

The categories

As described in table 1 six ascending levels (Levels 0 to 5) were developed. The general part gives an overview of the general standard of the student statements. Moreover, aspects such as the aim of the sciences, the genesis of knowledge, origin of ideas and questions as well as the research process are assessed. The system of categories was, first of all tested, based on 30 student statements to the different items. An expertise congruency of 78%, guaranteed the reliability.

	Level 0	Level 1	Level 2	Level 3	Level 4	Level 5
General level of expression of the student statements	Misinterpretation: No statement: senseless response	Basic response without reference to science	Statement was clear and the contents were correct; however, the level was basic	Statement is relatively indifferent; however, it allows for the interpretation of more advanced understanding	The clear statement reflects a more sophisticated understanding of science	Clear and exact statement with a more profound understanding of science
Aim of science		Aimless, science without information-oriented aspects	Orientation exists; science as a collection of data. Production of medicine and inventions	Aim is clearly formulated. Science is more than just taking information in: it's a search for answers	Science as a search for coherencies and verifiable explanations	Science presents us with more and more profound models/ explanations about the world
Aim of science		Aimless, science without information-oriented aspects	Orientation exists; science as a collection of data. Production of medicine and inventions	Aim is clearly formulated. Science is more than just taking information in: it's a search for answers	Science as a search for coherencies and verifiable explanations	Science presents us with more and more profound models/ explanations about the world
Genesis of knowledge		Aimless; science is pure action	No separation between knowledge and world; naïve realism	Commencing separation of knowledge and world	Science as a construction of knowledge	Science is cyclical, cumulative and modifiable"; Critical realism
Origin of ideas and questions		Aimless; science is pure action	Engineer's perception, does or doesn't function	Answering questions; understanding phenomena; fundamental mechanisms are not important	Fundamental mechanisms are important; each for principles and explanations, testability	Fundamental mechanisms are seen in larger contexts
Research process: Idea-experiment-Findings		The actions are separated from ideas and questions	No relationship Idea/ experiment. No processes are recognizable	Commencing relationship idea/ experiment: first processes are recognizable	Relationship idea/experiment: Finding are not explicitly important: Processes are clearer	Finding result in the development of new ideas; Processes are cyclical

Tab. 1: Different grades of understanding for the classification of student statements

The sample

The sample consists of 155 students of Berlin, Germany. Altogether eight classes from different districts in Berlin participated in the monitored questionnaire in class. Seventy-five per cent of the sample came from grade 6,25% from the grade 5. The participants were aged between 10 and 13 years. Almost 60% of the students were11 years old at the time of the survey, 37,4% were between 10 and 12 years old.

Gender distribution with 52% girls and 48% boys was almost equal. A larger part of the children (65%) went to primary school and about a quarter attended secondary school. The school education in Berlin normally lasts six years, however, after fourth class it is possible to change to a secondary school. One class (12% of the sample) came from a special needs school.

First results

The results of the children's questionnaire demonstrate the identified knowledge about Nature of Science among 10-12 year old students. The developed categories are suitable to assess key student statements in a written form.

Compiling the science understanding of 10-12 year old students

In the following the different levels of knowledge are presented, based both on individual exemplary questions as well as on the respective statements.

Aim of the sciences

Students who respond in level 1, do not link the sciences with a certain aim. The statements lack information-seeking aspects. At level 2, students recognize that scientific work is determined by a target, which, however, remains undetermined. Science is mainly regarded as a collection of facts or as a production of inventions and cures. About a fifth of the overall sample attains this level. Not many more attain level 3, by which the students comprehend science as a search for answers. Science benefits humanity, nature or environment. Only very few students reach the two highest levels, four and five. Level 4 contains student statements, which combine the aim of the sciences with the search for contexts and explanations. Surprisingly, level 5 is attained by one of the 155 students. This student responded that science gives increasingly profound and complex explanations about the universe. The student also describes the benefits of scientific work.

Level	Specimen student statements	Frequency in % [6]
1	„Trying out exciting experiments. “	13,5
2	“Finding out a lot of new things, e.g., new kinds of animals or a remedy to cure illnesses, where there has been no medicine up to now.”	21,3
3	“Find out more about nature.”	23,2
4	“The aim is to explain nature. People, animals, plants, stars etc.”	4,5
5	“The aim is to make new discoveries through research, in order to explain the world and to develop ourselves further. And to protect the world.”	0,6

Tab. 2: What is the aim of the sciences?

Level	Specimen student statements	Frequency in %
1	“From using the internet and reading.”	19,4
2	“You travel, find a few ‘things’. You research these ‘things’. Now you have made a new discovery.“	23.2
3	“By experimenting and observing.”	25.2
4	“Because many questions are asked and also because you then get to the bottom of things. And because a lot of things are detected by experimenting.”	3.2
5	“Researchers and scientists make hypotheses and then examine them closer.”	0.6

Tab. 3: Where do new discoveries come from in the sciences?

6 The frequency data does not add up to 100%, because Level 0 is not entered here. Level 0 contains misinterpretations of the question, no statement at all or totally meaningless responses (see Tab.1).

Genesis of science

If you look at student statements on knowledge genesis, then you have a similar picture which also occurs by the question relating to the aim of the sciences. Again here, the majority of the students reach level 2 and 3. In contrast to level 1, by which science is regarded as the pure production of positive effects, here the collection of knowledge genesis determines the knowledge genesis. The difference between level 2 and 3, which is attained by a quarter of the interviewed students, is that at the more advanced level a separation takes place for the first time between the world and knowledge. Moreover, level 2 students do not link discoveries with the activities of a scientist such as experiments and observations. Student statements at this level are distinguished by the fact that discoveries and inventions are simple matters and can be made without much bother. They follow the principle of naïve realism: "The scientist takes a walk in the forest and discovers something."

Level 3 is typical for student statements in which a certain processor orientation, formulation of questions and searching for answers can be detected. At level 4, students no longer regard science as a pure collection of facts, but more as an active construction of knowledge. This knowledge is understood as an image of the universe. Additionally, level 5 contains the assumption that scientists reflect on previously gathered knowledge and experiences. Knowledge from this perspective is, therefore, cumulative and alterable.

Level	Specimen student statements	Frequency in %
1	"They find some object and think something up about it."	22,6
2	"They research a lot and travel a lot around the world. When they do this, they discover a lot and then questions and ideas crop up. "	34.8
3	"They have questions, look for an answer and then have an idea."	11.6
4	"From reading books. By researching the work of other scientists and by reflecting."	3.2
5	"By looking at other experiments and formulating a hypothesis which they then attempt to substantiate by experimenting."	0.6

Tab. 4: Where do scientists get these ideas?

Deducing ideas and questions

Deducing questions and ideas plays a significant role in the scientific process. Many children's responses to the question: where do scientists get their ideas from, are located at level 1. They think that it is “sheer coincidence” what scientists do or that they even get their ideas from the “internet and television”. Also the ideas, for example, are only determined by the modes and wishes of scientists or their superiors. At level 2, which the majority of children attained, other scientists or experiences are aimed at as the source for the scientists’ questions and ideas. Student statements - gathered at level 3 of the overall sample - give an inkling of the scientific process. Only from level 4 onwards are cumulative and cyclical processes recognised and implicitly described. Just a single student was able to be allocated to level 5. The student had recognised the significance of previous work for formulating a hypothesis.

Research process [Relation Idea – Experiment]

Why do scientists carry out experiments? Table 5 illustrates that over half of the students in the second level responded. Students see the reason for an experiment in trying something out. For example, try something in order to find out if something functions or not (Engineer’s perception). Or try to find a cure to solve problems or even to learn something new. A typical response for this level is: “in order to find something out”. A connection between the experiment and a previous idea or question does not exist before level 3. According to student opinion at level 1, the focus of an experiment is on the effect that it aims to achieve. Another basis of action does not exist. This only occurs from level 3 onwards. Here, students become aware that an experiment results from a previous reflection and serves the purpose of answering a question or giving an explanation.

Level	Specimen student statements	Frequency in %
1	„They also want to earn their money. “	14,2
2	„In order to find something out. “	51,0
3	“If you don’t understand something, then you should at least try to understand it.”	14,2
4	„In order to prove and substantiate hypotheses. “	8,4
5	„In order to prove their theories or so that they can formulate new ones. “	0,6

Tab. 5: Why do scientists carry out experiments?

The answer: “If you can’t explain something, then you should at least try to understand it”, shows that the student regards the experiment as a contribution to understanding the issue. The testability of ideas by using an experiment becomes clear for the first time at level 4. Experiments are seen as contributions for the search for explanations and the development of ideas. Moreover at level 5, an experiment is based on a hypothesis and its development.

Research process: Findings and Evaluation of Ideas [Relation Findings – Idea]

What scientists have to do, according to student opinion, if the results of an experiment do not coordinate with their ideas or assumptions, is seen in Table 6. Level 1 contains 14,2% of the samples, which encompasses the statements that do not class the experiment in a work process. Either the experiment succeeds or you start again. The majority of students respond to this question around level 2. The agreement with as well as the rejection of an idea is based on simple observation or on a single experiment. If the experiment is repeated, then this happens without examining the reasons of the previous failure or an error analysis. A work process is only suggested from level 3. There, for example, the children mention that scientists have to repeat an experiment before changing their ideas. Level 4 contains student statements, which mention that several experiments are necessary in order to revise an idea. The results have to be reproduced. From level 5 onwards, the scientific perception process contains either a development or an idea (not only its examination), or it means finding a better explanation based on evidence which was gained from the experiments.

Level	Specimen student statements	Frequency in %
1	"Then they start again."	14,2
2	"They have to start a new experiment and are more successful. "	34,8
3	"Either the scientists change their ideas or they alter their ideas before attempting the experiment again."	20,6
4	"Scientists repeat the experiment and when it doesn't work out again, they just improve their ideas."	3,9
5	"They negate the hypothesis and develop a new and better one."	0,6

Tab.6: What do scientists have to do, when the results of an experiment do not coordinate with their ideas or assumptions?

Discussion

To study expert-layperson-communication in out-of-school learning environments and to compare the anticipation of scientists considering children's knowledge about aspects of the Nature of Science of children the status of the children's knowledge had to be measured first.

From literature concerning developmental psychology and didactics of natural science, categories are known to us which help us to classify students´ statements gathered at interviews about science as well as processes and methods. Moreover, the interviews incorporate information about different levels of understanding among students (Carey, 1989; Grygier et al., 2002; Smith et al., 2000; Sodian et al., 2002; Thoermer & Sodian, 2002). The systems of categories were developed further in this context and adapted, so that student statements, which were polled in a written questionnaire, are able to be evaluated. The new categories offers the possibility of recording junior students' science understanding, as well as reproducing established insights from literature (Aikenhead, 1987; Carey, 1989; Grygier et al., 2002; Lederman et al., 1998; Sodian et al., 2002).

True to form, a 10-12 year olds´ understanding of science is not very developed. Based on hypotheses, it becomes obvious with the help of individual questions that the majority of children associate the aim of science with "finding out something" (level 2), but do not specify the aim further. Additionally, the hypotheses on the scientific processes can be verified. A research process, with its cyclical and cumulative character, is at most implied at level 3 and only materialises at level 4 in the form of individual questions. Very few students attain this or the highest level 5.

The majority of students have little conception of cyclical and cumulative processes in the sciences. If you go into detail in the case of individual aspects of the research process, you can observe that a large number of students are in the position of associating the response to an idea with an experiment; however, the majority do not state that the reason for an experiment has something to do with examining an idea. The hypothesis, which was made at the outset, that science is seen more as pure activity (level 1) must be expanded in support of the insight that the majority of students understand science as gathering information (level 2). Everything considered 10-12 year olds have a very limited conception about the sciences and research processes. This is known from the literature mentioned above and could be verified with the help of the survey as well as the newly developed system of categories.

Outlook

In the broader sense, the students´ statements on the different levels have been used to develop a questionnaire with different items which represent the students´ knowledge on different aspect of Nature of Science. In a follow-up study, experts´ anticipation concerning the previous knowledge of students is examined with the help of this questionnaire. The experts will be employees of out-of-school learning environments like science museums, science centres, laboratories or other public institutions which do offer programs for students in that age. The aim here is to offer a contribution to improve aspects of science communication and especially the expert- layperson communication at out-of-school learning environments.

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