

MobiLLab Program Background Investigation

Verschaffen eines Überblicks des mobiLLabs

Directions for Program Improvement and Evaluation Research

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MobiLLab was designed by faculty at the University of Teacher Education in St.Gallen (German: *Pädagogische Hochschule St.Gallen (PHSG)*) to spark interest in science in secondary school pupils in the German-speaking part of Switzerland. Now in its fourth year of operation, the mobiLLab team would like to evaluate the program's effectiveness to inform further development. Specifically, we want to better understand how mobiLLab affects pupils' science and technology interest, attitudes and knowledge development, and how positive changes can be sustained. The background investigation brings together information from observations of and informal interviews with teachers and pupils during 14 mobiLLab school visits, interviews with mobiLLab team members, interviews with representatives from similar programs worldwide and a review of relevant materials. The results paint a picture of how the mobiLLab program operates, its intended outcomes and information about other programs and related research, which point to relevant themes and targets for program evaluation and improvements. Feedback from educators, researchers and others who read this report is very welcome.

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1. Summary

MobiLLab is a high-technology mobile science laboratory program developed by faculty at the University of Teacher Training in St.Gallen, Switzerland (German: *Pädagogische Hochschule St.Gallen (PHSG)*) to promote science and technology interest among youth in the German-speaking cantons of Switzerland. To collect information that will inform a program intervention and evaluation, the author conducted a background investigation of the program between October 2012 and April 2013. Investigation activities included observations of and informal interviews with teachers and pupils during mobiLLab school visit, interviews with mobiLLab team members, interviews with representatives from similar programs worldwide and a review of relevant materials.

Drawing on investigation results, the author worked with the mobiLLab team to formulate a 1-page flow-chart, called a Logic Model, that captures how program resources and activities are intended to produce outputs and outcomes. As a depiction of how the mobiLLab program is supposed to work, the Logic Model is the mobiLLab team's Theory of Action. According to the Logic Model, promoting a "technophilic" attitude in pupils is the core outcome for the program. A technophilic attitude is an attitude of awareness, affinity and curiosity about science and technology. The mobiLLab team identified program activities and outcomes that are important for promoting technophilia in pupils. These "hot spots," or areas of greatest concern and possible impact, are pre-visit activities and materials; design of experiment stations; teacher attitudes and teaching approaches; and training of pre-service teachers who serve as mobiLLab coaches.

Interviews with representatives from eight similar programs show that while programs vary in the volume of pupils they serve and in program depth and breadth some themes and commonalities exist. Program representatives agreed that promoting pupils' interest in science and experimentation depends to a great degree on their teachers' teaching approach and attitudes about science and technology. Aspects of a mobile laboratory experience reported as important for promoting pupils' science interest and knowledge development include keeping science content simple; helping pupils relate science principals to the world around them; providing opportunities for pupils to develop and test questions, hypotheses and experimental designs; giving pupils a chance to work independently; holding discussions about pupil questions before or after experimentation; visiting each class group more than once; and even driving a slick-looking truck and employing coaches who show pupils that science can be "cool" and "fun." Some programs employ university students and recent graduates to organize and staff school visits in order to reduce costs and provide coaching from people closer in age to pupils.

Existing studies of museums, science learning centers and mobile laboratories focus on an array of parameters about pupils that have mostly to do with their attitude about science, interest in science, knowledge about science, perceptions of science in society and their career ideas. A cursory literature review conducted with the mobiLLab logic model "hot spots" in mind reveal a list of relevant evaluation frameworks and approaches. While these areas - self-determination theory, novelty spaces, teacher attitude, teacher and pupil science self-identification, effects of pre- and post- activities, interest development theory - have been investigated for classroom and museum environments, few studies look into science center and mobile laboratory experiences. However, some studies have developed and tested lesson plan interventions and measurable indicators for pupil and teacher variables that can inform mobiLLab program evaluation and improvement.

Synthesizing information from interviews and observations with insights and tools from other studies, the author and several mobiLLab team members identified specific target actions, evaluations and areas for further inquiry that can guide mobiLLab program development.

2. Description of the MobiLLab Program

Through interviews with mobiLLab team members, participating in school visits and reviewing program material and related literature, the author developed an understanding of MobiLLab Operations, described below. Also shown in this section are a Situation Description and a flow-chart Logic Model developed in cooperation with the mobiLLab team; it depicts how program resources and activities are intended to produce outputs and outcomes. The detailed approach for and further results of the background investigation are described in the following sections of the report.

2.1 Overview

Since its inception in 2009, the University of Teacher Education in St.Gallen (PHSG) has operated the mobiLLab program as a vehicle for providing hands-on training in natural science experimentation with high-technology equipment to pre-service teachers, secondary school pupils and in-service teachers. The program was designed for pupils aged 14 to 16 years old who attend secondary school level 1 (German: *Sekundarstufe 1*). These pupils generally either pursue further vocational training or transfer into the university preparatory secondary school level II (German: *Gymnasium*). Each September, visits are scheduled to schools whose teachers have applied. In accordance with its funder contract, mobiLLab schedules a minimum of 20 school visits per year in the Swiss canton St Gallen and some nearby cantons.

The mobiLLab team

The mobiLLab team consists of faculty and staff at the University of Teacher Education in St.Gallen, Switzerland (German: *Pädagogische Hochschule St.Gallen (PHSG)*). The team maintains experiment post equipment, trains teachers and makes decisions about updating experimental posts and program materials. During their fourth year of study, students (pre-service teachers) participating in the Teaching Natural Science Program at the PHSG are trained to coach pupils during mobiLLab school visits. Each student learns how to assemble equipment and carry out experiments at four of the twelve posts, for which they will coach pupils during at least one mobiLLab school visit. Since 2012, several retired teachers and retired university professors have joined the team as coaches.

NOTE: PHSG students (pre-service teachers) participate in 9 course hours (each 45 minutes) of training at mobiLLab experimental posts. During the training, these pre-service teachers acquire knowledge about related science theory mostly through self-study training. After their training, students schedule a session to practice assembly of the equipment for their post. If they feel they need more time to learn how to assemble the equipment or conduct the experiment procedure that they will be responsible for during mobiLLab deployments, students may spend some hours of self-study training.

For each school visit, the mobiLLab “deployment team” typically consists of one mobiLLab operations staff person, one or two PHSG faculty members, three student coaches (PHSG pre-service teachers) and sometimes a coach from the pool of retirees.

Teacher Orientation and Pupil Preparation

For teachers to be eligible to apply for a mobiLLab visit, they should first participate in a one-day orientation training, held each August at the PHSG. After this orientation training, teachers may apply for mobiLLab to bring up to 12 laboratory experiments into their classroom for a morning or afternoon. During a typical half-day at participating schools, there are four, forty-five minute school periods. Teachers are asked to work with pupils in advanced of the mobiLLab visit to choose their four experimental posts. At orientation training, mobiLLab trainers recommend that teachers have pupils prepare for their four experimental posts by reviewing elearning tutorials, which are 10- to 13-minute illustrated audio sequences that introduce the theory, equipment and sometimes applications for each experimental post. The last part of each elearning tutorial is a quiz consisting of about 10 questions. Trainers also ask teachers to have pupils prepare their own questions for each experimental post. There are worksheets (*Journalblätter*), which include questions for pupils to consider, blank spaces for pupils to write down their own questions and blank spaces for pupils to record the results of their experimentation. The elearning tutorials and a glossary of terms are available through the password-protected mobiLLab webpage <http://www.mobillab.ch/>. At another password-protected webpage teachers can gain access to the *Journalblatt* and experimental post information including theory, experimenting instructions and electronic versions of the posters displayed during the mobiLLab visit.

A typical school visit

A typical school visit begins at the PHSG building, where the deployment team loads the experiment equipment into a van and drives to the school. The mobiLLab van arrives at the school before classes start and sets up experiment stations in a classroom. Pupils work in pairs, independent of frontal instruction, ideally following through the instructions at each station and also exploring their own questions through experimentation. Sometimes pupils bring objects from home to test, such as tap or pond water to analyze via Ion Chromatography and metal objects to analyze with X-ray Fluorescence.

MobiLLab's 12 Experiments

MobiLLab experiments are listed below, along with an example question.

Table 1: List of mobiLLab experiments.

Infrared camera <i>Is our classroom well insulated?</i>	Pyrometer <i>Is the „cold metal“ in our classroom really colder than the „warm wood“?</i>
X-ray Fluorescence <i>Does my tongue ring contain any poisonous metals?</i>	Visible Light Analysis with Spectrometer <i>Why do colors from a fluorescent light look differently than sunlight?</i>
Exhaust Analyses <i>Does my moped produce the same exhaust when idling as when accelerating?</i>	Spiroergometry: Respiratory Gases <i>At what level of physical exertion does my body burn only carbohydrates?</i>
Ultraviolet Protection <i>Do my sunglasses protect my eyes from the sun's ultraviolet radiation?</i>	High-speed camera <i>Do air- and water-filled balloons burst in the same way?</i>
Industrial Microwave Synthesis	Household Microwave Applications

Can I produce a perfume in a few minutes?	Is it possible to produce popcorn in a microwave?
Ion Chromatography <i>Is our tap water as "pure" as mineral water?</i>	Gas Chromatography <i>What is the chemical composition of the gas from a lighter?</i>

2.2 MobiLLab Program Situation and Intended Outcomes (Logic Model)

The Situation Description below summarizes the background and reasons for a program evaluation. Following it is a flow-chart Logic Model that depicts how program resources and activities are intended to produce outputs and outcomes. The documents were created following the approach outlined in the guidebook *Enhancing Program Performance with Logic Models* (Taylor-Powell 2003). Based on information from background investigation activities, particularly interviews with mobiLLab team members and interviews and observations during school visit, the author drafted the Situation Description and Logic Model. Then, through discussions with the full mobiLLab team, the documents were reworked to create something acceptable to all.

Situation Description (with summary points in German)

In spite of good science and math scores in secondary school (Eichenberger 2010), young people in Switzerland, as in many other developed countries, show low interest in these subjects (Sjøberg 2010). Moreover, too few young Swiss who show talent in science and math are completing university degrees in these disciplines and they are choosing non-tech professions or professions outside of industry (MINT-Meter 2012; Vogel-Misicka 2012). This trend comes at a time when demand for science and technology graduates is growing and importing high-tech and industry workers has become necessary in Switzerland as well as in many parts of Europe (High Level Group on Increasing Human Resources for Science and Technology in Europe 2004; Haas 2012; PresenceSwitzerland. 2012). To address the lack of "home-grown" industry and technology workers, mobile laboratory programs have started operating in countries including Germany and Switzerland.

- Trotz guten Noten in Naturwissenschaft und Mathematik, zeigen Jugendliche in der Schweiz wie auch in vielen anderen entwickelten Ländern, wenig Interesse an diesen Fächern.
- Zu wenig junge Leute, die in Naturwissenschaft und Mathematik talentiert sind, schliessen ein Universitätsstudium in diesen Fächern ab und wählen technische Berufe.
- Aufgrund dieses Zustandes müssen ausländische Fachkräfte für die Industrie akquiriert werden.

By bringing laboratory experiments, scientists and science coaches into secondary school classrooms in the German-speaking part of Switzerland, mobiLLab gives pupils an opportunity to experience inquiry-based science experimentation. Studies conducted in Europe and the US show that visits with mobile laboratories and science centers sometimes result in development of pupils' science interest attitude and knowledge immediately after a visit and that any changes tend to fade over a matter of one or two months (Barmby 2005; Jarvis 2005; Brandt 2008; Pawek 2009; Dowell 2011; Gassmann 2012).

- Durch Bereitstellen von Laborausstattung, Naturwissenschaftler und Lehrpersonen im Klassenzimmer, ermöglicht mobiLLab den Schüler und Schülerinnen der Sekundarstufe in der Deutschschweiz, inquiry-based wissenschaftliches Experimentieren zu erfahren.

- Laut Studien von Europa und den USA, mobile Labors und naturwissenschaftliche Zentren können das Interesse, die Einstellung gegenüber und den Wissenserwerb in Naturwissenschaften bei Schülern und Schülerinnen fördern aber nach ein oder zwei Monaten verebben solche Veränderungen wieder.

Now in its fourth year of operation, the mobiLLab team would like to evaluate the program's effectiveness to inform further development. Specifically, we want to better understand how mobiLLab affects pupils' science and technology interest, attitudes and knowledge development, and how positive changes can be sustained.

Um die Weiterentwicklung des Programms zu planen, will das mobiLLab Team dessen Wirkung bewerten. Wir wollen insbesondere besser verstehen, wie sich mobiLLab auf das Interesse der Schüler und Schülerinnen für Naturwissenschaften und Experimentieren, auf ihre Einstellungen dazu und auf den Wissenserwerb nachhaltig auswirkt.

Logic Model Flow Chart

The logic model shown on the next page is a simplified picture of the logical relationships among mobiLLab program resources, activities and the benefits and changes that result. In order to design an evaluation to reasonably test the program theory, the program needs a clear depiction of the theoretical base. A logic model provides that description (Taylor-Powell 2003).

During a group meeting, the mobiLLab team identified components of the logic model that they are most concerned about and where better understanding and improvements could make the biggest difference. These "hot spots" are shown in bold on Logic Model and described here.

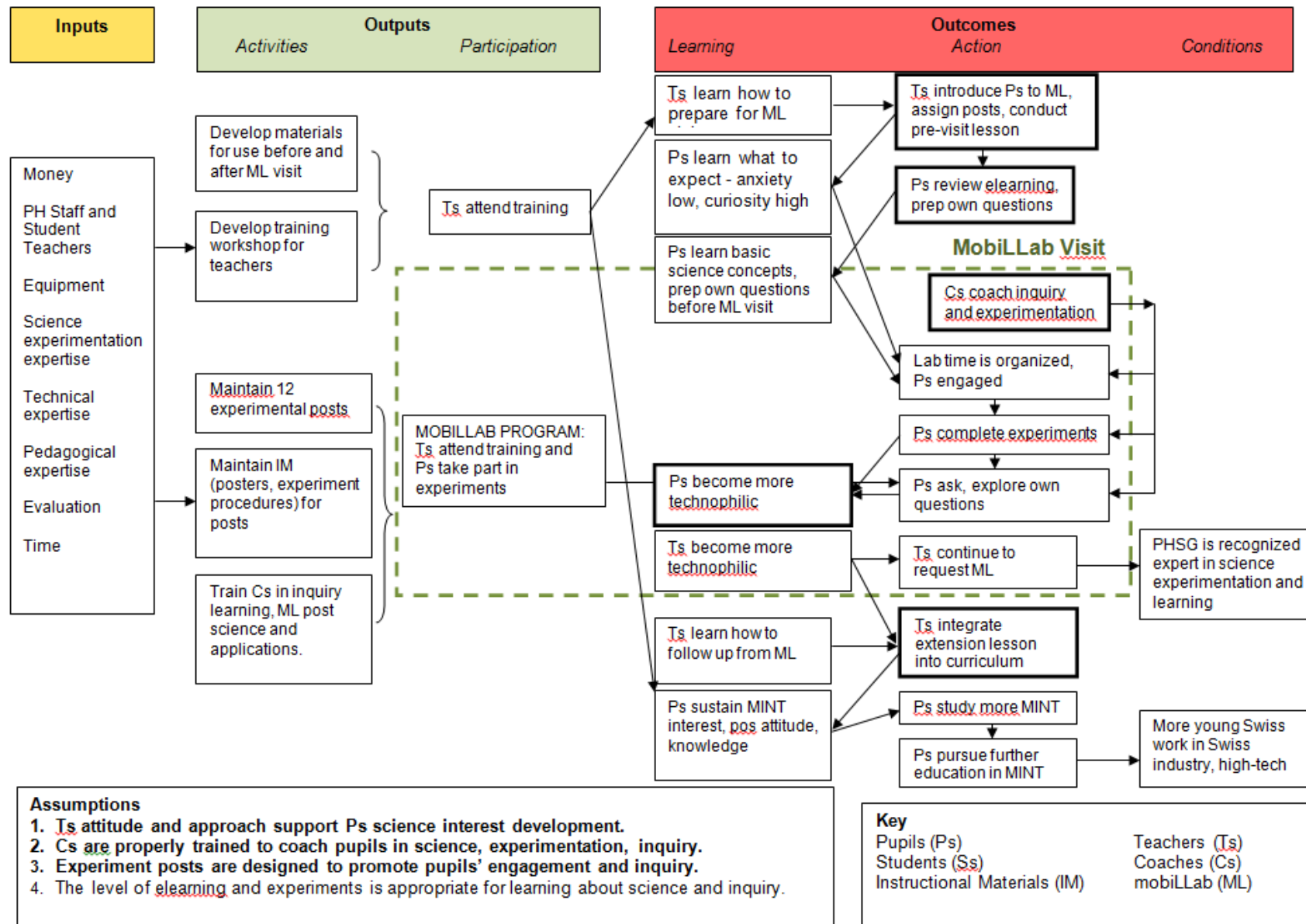
List 1: MobiLLab logic model "hot spots," or areas of greatest concern and possible impact.

- Pupils become more "technophilic." The central goal of the mobiLLab program is to develop pupils' interest in, and positive attitude about, science and technology. Some mobiLLab team members used the term "technophilic" to describe the awareness, curiosity and affinity they envision pupils having for science and technology.
- Pupils review elearning, prepare their own questions. The most talked-about concern by the mobiLLab team is that some groups of pupils are not well prepared for the mobiLLab visit. When they learn that pupils have not reviewed the elearning nor formulated their own questions for the four experiments they will conduct during the mobiLLab visit, they observe that they are often less engaged in experimentation.
- Teachers integrate extension lessons into curriculum. A related concern is about how teachers link mobiLLab and classroom work after the mobiLLab visit, which likely affects pupil retention of science and experimenting interest. Some teachers already conduct follow-up activities, which many team members believe influences pupil interest and knowledge retention. Interestingly, the mobiLLab team noticed from the logic model that if teachers become more "technophilic", perhaps they would probably be more motivated to embed mobiLLab content in pre and post-visit classroom lessons.
- Assumption: Teacher's attitude and teaching approach support P science interest development. Some mobiLLab team members and even some teachers described how the attitude of teachers is a very influential factor on pupils' science and technology interest development.

- Assumption: Coaches are trained to properly coach pupils in science and inquiry. Another focus is the coaching the pupils experience during mobiLLab visit. The team feels that coaching is a key part of pupils understanding, enjoying and becoming inquisitive about the experiments. At the same time, some coaches said during interviews that they did not always have opportunities to properly learn how to assemble their experimental posts. In addition, training for coaches does not cover approaches for inquiry-based coaching and coaches do not often use IPADS during coaching, two aspects the mobiLLab team would like to change.

- Assumption: Experiments are designed to promote pupil engagement and inquiry. A topic discussed during a mobiLLab team meeting and also in interviews with mobiLLab coaches is the differences between experiment stations. Concerns include
 - At some experiment stations, applications from everyday life should be more explicit.
 - At some stations, relation to basic science concepts should be more explicit.
 - Some experiments are more complicated than others. This means some pupils are finished earlier than others and, if they do not have another task to complete, they become bored and disruptive.
 - Because some experimental stations are less complicated (Infrared Temperature Measurement) or involve a lot of waiting time (Gas Chromatography) and other stations require at coach to be present all of the time (Exhaust Gas and the Spiro-ergometer) coaches can either have too little or extra capacity to work at their posts. Moreover, pupils at the less complicated posts, tend to become bored.

Figure 1: MobiLLab Logic Model



3. Approach for the Background Investigation

This background investigation of the mobiLLab program took place between October 2012 and April 2013. Several mobiLLab team members assisted me in generating a list of questions, listed below, to explore during the investigation. The investigation was conducted in an exploratory manner to identify focus areas for program improvement and evaluation research and not meant to be comprehensive or to follow a rigorous protocol.

List 2: Guiding questions for the background investigation

- What are the goals and objectives of mobiLLab?
- How do teachers and pupils prepare for a visit from mobiLLab? To what degree do teachers and pupils use E- learning materials?
- In what ways does teaching approach influence the degree to which pupils profit from mobiLLab?
- How do teachers and pupils describe their mobiLLab experience?
- To what degree does mobiLLab motivate pupils to study and pursue careers in MINT (Math, Informatics, Natural science, Technology) discipline areas? To what degree does mobiLLab support development of MINT competences?
- What standards and programs influence how MINT subjects are taught in Canton St.Gallen and Switzerland?
- How do these standards and programs influence pupils' academic experience and career choice and performance?
- What similar programs exist worldwide and what do they offer?
- What challenges, successes and evaluations have similar science learning programs experienced
- What ideas do stakeholders have for using and improving mobiLLab?

Background Investigation Activities

Activities included reviewing mobiLLab program materials, relevant economic trend reports for Switzerland and Europe and research articles; participating in mobiLLab deployments (school visits); and interviewing mobiLLab program stakeholders and representatives of other programs. Interviews and conversations were conducted in German or English, depending upon the preference of the interviewee, and all interview guides were written in English. Interviews were informal (not taped), non-structured and open-ended discussions. Interviewees received a list of questions before the interview, called a TTT (time to think) strategy, in order to encourage reflection and well-thought-out responses. Figure 2 shows the scope of the investigation.

Reviewed materials

- MobiLLab materials: Curriculum for teacher training, website, E-learning videos, experiment instruction materials, pupil survey.
- Standards and programs that influence math and science learning from Canton St.Gallen and Switzerland.
- Websites of similar science learning programs.
- Evaluation reports from some similar programs.
- Reports about education and employment trends in Switzerland.
- Articles about related evaluations and research studies.

Participated in mobiLLab deployments

While participating on 14 mobiLLab school visits, the author made observations, interviewed teachers, spoke with pupils and talked with the deployment team about their observations.

Interviewed mobiLLab stakeholders

Twelve exploratory in-person interviews introduced me to the perspectives of mobiLLab stakeholders (German: *Interressensvertreter*): operations team members from PHSG, science faculty at PHSG, PHSG students who serve as coaches, retirees who serve as coaches, PHSG administrators and also participating teachers and pupils.

Interviewed managers of similar programs

Through eight interviews by phone, Skype or email with managers from a handful of similar science learning programs the author sought to better understand the landscape of program formats and evaluation designs for programs similar to mobiLLab. Attending the October 2012 GDCP (Society for chemistry and physics didactics / *Gesellschaft für Didaktik der Chemie und Physik*) conference also informed me about other similar programs and related evaluation work.

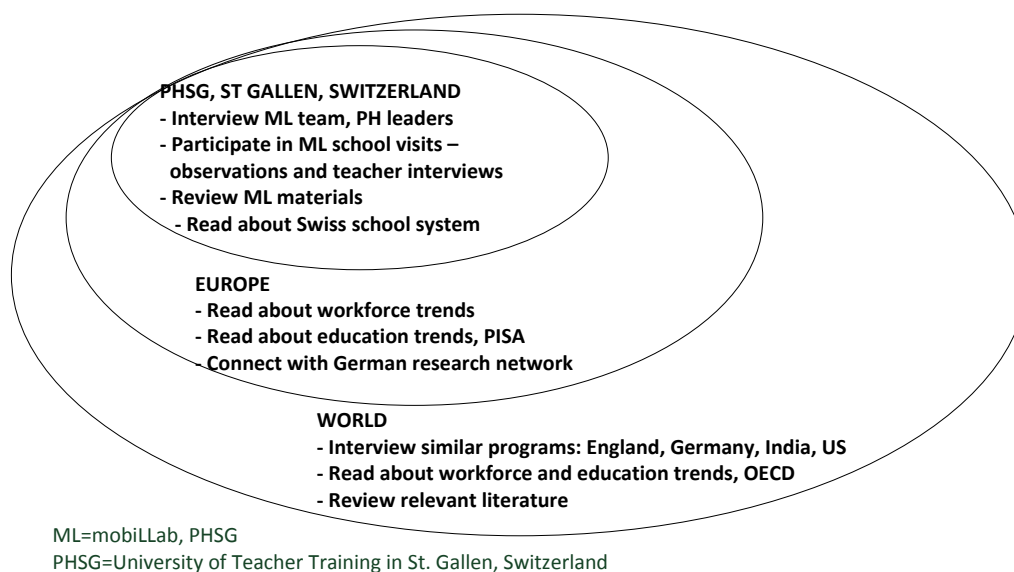


Figure 2: Scope of the background investigation.

4. Results: Insights into the MobiLLab Program

A first step in the background investigation was to understand mobiLLab goals, contexts and early feedback from participants.

4.1 Program Goals: awaken interest and promote 'technophilia'

The mobiLLab website showcases quotations from famous scientists Marie Curie and René Thom. These quotations describe the wonder, beauty, adventure and play one can experience with science experiments, the kinds of sensations that belong to the child in all of us.

A scientist in his laboratory is not only a technician: he is also a child placed before natural phenomena which impress him like a fairy tale. (Ein Gelehrter in seinem Laboratorium ist nicht nur ein Techniker; er steht auch vor den Naturgesetzen wie ein Kind vor der Märchenwelt.)

Marie Curie (1867–1934), Polish-born Chemist, Physicist and Nobel Prize winner

The only conceivable way of unveiling a black box, is to play with it. (Der einzig denkbare Weg, um das Innere einer Black Box aufzudecken, ist, damit zu spielen.)

René Thom (1923-2002), French Mathematician and Fields Medalist

Some stakeholders including teachers, industry representatives who visited classes during mobiLLab events, and mobiLLab team members, spoke with detail and precision about what it means to interest pupils in science and math. They spoke about fostering pupils' awareness of science in the world around them, their comfort with science and technology and their opportunities to try out scientific inquiry. Specific expressions that PHSG faculty identified that define technophilia are captured in the "see-like-ask" diagram shown as

Figure 3.

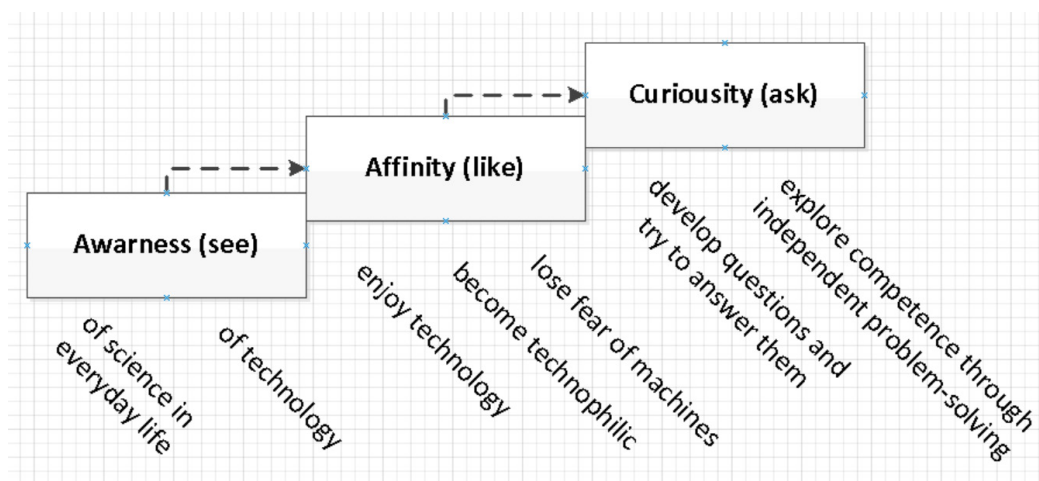


Figure 3: Promoting "technophilia" in pupils involves their awareness, affinity and curiosity.

Interest leads to competence and career choice

Awakening pupils' interest in science was named by all interviewed mobiLLab stakeholders as the most important goal for mobiLLab. Some explained that awakening interest among pupils in science leads to fulfillment of two other important program goals: supporting development of pupils' MINT (Math, Informatics, Natural Science and Technology; German: *Mathematik, Informatik, Naturwissenschaften und Technik*) competences and piquing pupil interest in MINT careers (relation shown in Figure 4).

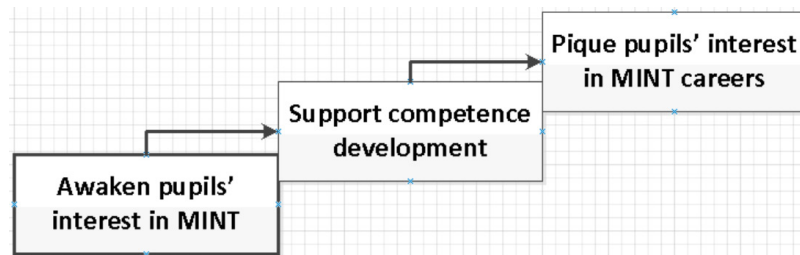


Figure 4: Core program outcome: awaken pupil's interest in MINT sciences.

Sustaining interest and positive attitude

During interviews, many stakeholders said the program would be most effective if pupil gains in science interest and knowledge could be sustained, adding a temporal dimension to these goal concepts.

PHSG Profile: experts in science and experimentation learning

Stakeholders also see the mobiLLab program as an important part of the PHSG profile as an institution recognized for its expertise in science and experimentation learning. That is, the program provides pre-service teachers who serve as mobiLLab coaches with the opportunity to work in a learning laboratory setting. MobiLLab is also a vehicle for serving in-service teachers, who learn about high-technology experimentation and related pedagogy during the orientation training for mobiLLab and by participating in experimentation during a mobiLLab visit.

4.2 MobiLLab Contexts

Several contexts are highly relevant to mobiLLab.

- Youth in developed countries show less interest in science
- Influence of education standards, guidelines and programs
- PHSG-MINT Partnership
- Worlddidac Award

Youth in developed countries show less interest in science

In the last decade, some studies have shown a general decline of children's enthusiasm for science with age in the USA and Europe (Jarvis 2005). Recently the ROSE (Relevance Of Science Education) project surveyed about 40 countries around the globe to find that youth in more developed countries are less interested in science and have more negative attitudes towards science than in less developed countries (Sjøberg 2010). Similarly, results from PISA 2006 indicated a tendency for pupils in countries with low knowledge scores in science to show relatively high levels of interest in science, while pupils in high-achieving countries show relatively lower levels of interest in science (Bybee 2011). This echoes results of studies in Germany a decade early (Hoffman 1998; Prenzel 2000) that showed pupils' interest in natural science, and physics and chemistry in particular, decreasing as they proceed through secondary school. Resource-poor Switzerland is especially vulnerable to this trend, as it lacks not only raw materials but also qualified, motivated workers who can maintain healthy economic development through their talent and innovation. The trend may also have implications for society, according to the ROSE report: "These negative attitudes may be long-lasting and in effect rather harmful to how people later in life relate to S&T as citizens."

Background investigation activities turned up evidence of this trend and suggest some possible reasons. Evaluation results from the Lab in a Lorry mobile laboratory program in Great Britain exemplify this trend, where participation with the mobile laboratory made 37% want to study more science, but made only 14 % want to become scientists (Barmby 2005). Some mobiLLab team members and leaders of similar programs talked about how the *image* of careers in science and industry are unattractive to youth in Switzerland, particularly in comparison to work as a banker or salesperson. Similarly, a number of studies in Germany a decade ago, summarized by Prenzel (2000), show that science subjects are not highly valued by pupils' families and peer groups. Moreover, these studies uncovered a common belief that the ability of learning science and mathematics is primarily a matter of being gifted, suggesting that unless pupils are gifted, efforts to study science are not really worthwhile.

Influence of Swiss Educational Programs and Guidelines

Currently the 21 German-speaking cantons of Switzerland each have their unique, official curriculum (German: *Lehrplan*) for primary and secondary education. Now all 21 cantons are developing one common curriculum, called *Lehrplan 21*, which is slated to be in use by 2016.

Teachers and mobiLLab team members described how existing education programs and guidelines (described in detail in the Appendix) have differing degrees of influence teaching and also pupils' academic experiences and career goals. Moreover, the programs are sometimes at odds with one another. For example, *Stellwerk* is an online test that pupils take that does not affect their school grade, but serves rather as an indicator of strengths and challenges. Teachers explained that because teachers and pupils are required to use it, and because some employers ask for a *Stellwerk* score on pupils' applications, it has become a quasi-standard to which they teach. They describe how any content in the curriculum that is not emphasized in the *Stellwerk* test, as well as non-content aspects of the curriculum, such as teamwork and learning strategies, are be-

coming a lower priority in Swiss education. For example, one teacher commented that the time (school hours) for his Natural Science and Technology (German: *Natur und Technik*) course has decreased in the last 5 to 10 years as a result of cantonal curriculum decisions, making it harder to cover curriculum topics. To begin to test some of these inferences, thirteen teachers were asked to rate how influential Stellwerk, their cantonal curriculum, mobiLLab, national standards and PISA are on 1) teaching and learning, 2) pupils' academic performance, 3) pupils' career choice and 4) pupils' ability to enter the workforce. While we should not draw broad conclusions based on ratings from this small group of teachers, it is worth noticing where their responses match (standard deviation less than one), which are shown in bold.

- Stellwerk is seen as having an extremely high influence on *teaching and learning* and a moderate influence on *pupil's workforce entry*.
- Cantonal Curricula is thought to highly influence *teaching and learning* and *academic performance* and moderate influences *pupil's career choice* and *workforce entry*.
- For mobiLLab, teachers' ratings varied. Some teachers said that if a mobiLLab visit would occur before pupils have chosen their apprenticeship, it would more strongly influence *career choice*.
- National standards and PISA are seen by teachers as having little or no influence on these factors.

Table 2: Influence of Swiss programs and guidelines on pupils and teachers.

Guideline/ Program	Influence on			
	Teaching and learning	Academic performance	Career choice	Workforce entry
Stellwerk online private test	Extremely high	<i>moderately</i>	<i>moderately</i>	moderately
Cantonal curriculum	highly	highly	moderately	somewhat
MobiLLab	<i>somewhat</i>	<i>somewhat</i>	<i>moderately</i>	<i>somewhat</i>
EDK (HarmoS) national standards	<i>somewhat</i>	<i>somewhat</i>	<i>somewhat</i>	<i>somewhat</i>
PISA standards	<i>somewhat</i>	somewhat	not at all	not at all

PHSG -MINT Partnership

With questions about how to make careers in MINT more attractive, the PHSG created the *MINT Partnerschaft* program. Through coaching by PHSG administrators and faculty, this pilot program fosters local partnerships between industry and secondary schools. Goals are to 1) offer pupils as well as their teachers an authentic picture of what it is like to work in vocational fields, 2) give pupils hands-on experiences at real workplaces and 3) pique pupils' interest in science and technology careers. The pilot phase began in 2012 and will run for three years. At the time this document was published, the project had involved four industry partners and eight teachers and their pupils.

Worlddidac Award

In 2012, mobiLLab was among a small number of education programs awarded the Worlddidac Award <http://www.worlddidac.org/>, an internationally recognized distinction for educational resources. Every two years an expert panel evaluates applicants' education products and programs against clearly defined criteria on educational and didactic program elements in several categories: basic aspects, educational value, design and sustainability.

4.3 Pupil and Teacher Feedback

Comments from teachers and pupils during the fall of 2012 give a first glimpse into their experiences with the mobiLLab program.

How to teachers embed mobiLLab in their classroom teaching?

Fourteen teachers commented on preparation with their pupils for a visit from mobiLLab. Teacher practices fall into several categories, revealing possible variables to track during a study. Also, some teachers customized our preparation suggestions for their pupils, offering examples for improving mobiLLab materials and for optimizing mobiLLab's teacher orientation training.

- About half of the teachers said they asked pupils to choose their own experiments, however sometimes pupils complained that they did not receive their first choice.
- Almost every teacher said that they asked their pupils to look at the elearning for the four experimental posts they plan to work with. About one-fourth clearly stated that pupils looked at the elearning during class time. One teacher explained how she saw some pupils quickly "clicking through" the e-learning audio sequence and quiz and imagined that they therefore did not retain very much from the elearning.
- Teachers say pupils spent two to eight hours on preparation, with most spending three to four hours.
- About one-third of teachers asked pupils to fill out the *Journalblatt* worksheet, which asks pupils to formulate their own questions about experiments. Some teachers asked pupils to hand the *Journalblatt* in and some asked them instead to use it to create a presentation.
- One-third to one-half of pupils brought their own questions for experiments and about one-third brought their own objects to test.
- About one-third of teachers assigned follow-up assignments, where pupils complete a short report or give a short presentation for one or more experiments they worked with.
- Some teachers took unexpected, sometimes innovative approaches:
 - One teacher described how even though he did not attend mobiLLab training (his colleague did), he developed an involved preparation for his pupils by following an article on the mobiLLab website that quotes a teacher who described an ideal preparation.
 - Several teachers customized the *Journalblatt* worksheet for their pupils.
 - As part of the experiment selection process, one teacher asked pupils to justify their 'top picks' and gave pupils with well-described justifications at least one of their favorite posts.

Reasons teachers give for bringing mobiLLab into their classroom – Fall 2012

- MobiLLab covers topics found in Stellwerk and the cantonal curriculum.
- The step by step instructions, coaching and support from the mobiLLab team and the fact that mobiLLab comes to the school make it nice to work with.
- Pupils can experience some independent learning time that is not teacher-led.

- Compliments the other projects the pupils are involved with, such as tours of industry facilities and hands-on science projects.
- This opportunity for pupils to experience experiments is valuable.
- Pupils can work with complicated instruments and build their confidence.

Other comments during mobiLLab visits – 2012-2013

- At the end of some visits, teachers polled pupils in a full group and many gave positive comments such as “interesting” and “unique” about their experience.
- Some pupils and teachers describe the mobiLLab elearning material as helpful while others describe it as being too difficult or boring. Several teachers suggested that the elearning videos start with descriptions of real-world applications, explaining that it is easier to motivate pupils to read and watch if they learn first about something related to what they already know.
- Some teachers said the posters next to each experiment effectively illustrate science principals at a good level for pupils.
- One teacher mentioned that he finds visits to the XLAB in Göttingen, Germany are a great experience for his pupils.

November 2012 Weesen - comments from pupils

Highlights from one-page texts written by pupils (12 from the class 2 and 15 from class 3), translated into English.

- I found mobiLLab good because you could experiment on your own.
- The experiments were fun and helped me learn something.
- It was informative and interesting. It was something different than learning only, you could try and try. I found it very good and I liked it.
- We did not find mobiLLab that interesting, because the experiments took so long. The instructions and explanations for experiments were sometimes a bit difficult.
- MobiLLab was pretty good; sometimes it was an experiment explaining something difficult. But the coaches explained everything well. There were a lot of things to try out and it was not always all that interesting. The experiment in the big microwave took too long.
- I liked mobiLLab a lot. It had many different things that you could try out.
- It was a good experience, and there were many things you could explore.

5. Results: Insights from Similar Programs

Interviews conducted with representatives from eight similar programs in Germany, Great Britain, India, Switzerland, and the US provide information about how their goals, operations and challenges, and also turned up several evaluation studies. Goals and suggested practices from other programs are described below. On the following pages are two tables that showcase *Some Similar Programs Worldwide* and a *Descriptive Matrix of Mobile Laboratory Evaluations*.

Overview

All but one of the programs the author contacted serve upper secondary schools and some also serve middle schools. For five of the programs, pupils conduct experiments inside a bus. Three programs bring experiments into or next to the school. Because the Paul Scherrer Institute is a science center, pupils visit as a field trip. Programs vary widely in the number of teachers and pupils they see each year, in the way teachers are involved before, during and after the visit, in the depth and breadth of science content, and in the degree to which pupils generate hypotheses and experimental designs. Still, some themes emerged from interviews and they are listed as suggested practices here (for more details see the Appendix).

All program representatives said they aligned their activities and experiments with school system curricula and seek to promote positive attitudes among pupils about science. Most representatives said that the single greatest influence on how much pupils' profit from their programs are their teachers, and some specifically described the importance of teacher interest in science and teaching approach. Some commented that a large bus brings some visibility value, or "flash", but that otherwise they function exactly like a science center. Twenty-two mobile laboratories in the US and one in Hong Kong are members of the Mobile Laboratory Coalition <http://www.mobilelabcoalition.com/>.

Goals of other mobile laboratory programs

Like mobiLLab, many interviewed mobile laboratory program representatives emphasize a primary goal of sparking pupils' interest in science and, secondarily, supporting development of competence in math and science and interest in related careers. For some mobile laboratory programs, knowledge gains are a priority outcome. Also like mobiLLab, many programs have an equity-related goal of bringing a laboratory experience to pupils, sometimes to schools who have far less equipment than others. Additional goals described by program leaders include promoting awareness of science in everyday life, appreciation for the usefulness of science to improve the human condition, improving public perception of science, demystifying sciences such as physics and molecular biology that are not depicted on popular television crime shows, promoting a sense of citizen responsibility in young people and supporting teacher professional development.

List 3: Suggested practices from other programs.

Awakening pupils' interest in science

- Keep the science content simple and give pupils opportunities to 1) relate it to the world around them and 2) develop their own questions, hypotheses and experimental designs.
- Pupils should take responsibility for their own learning; work independently of supervision and alone rather than in pairs.
- Visit each class more than once. Identify talented pupils and promote them to helpers and "trainers" and/or direct them to science enrichment activities.
- Hold a discussion about pupils' questions or results before and/or after their experimentation.
- Present experiments as real-world problems.

- The truck is an advertisement that the pupils are doing something new, interesting and authentic, and when coaches encourage the pupils to have fun, it shows that science can be “cool.”

Operating mobile laboratories now and in the future

- Staff the mobile lab with instructors who have just finished college, who because they are younger can sometimes make a better connection with pupils and incur lower operating costs.
- Teacher input/ involvement is critical for designing new programs and maintaining a high-quality program.
- Consider using computer-supported experiments, which has high up-front costs but significantly lower maintenance costs. Game-based learning (MdBioLab is considering Smart Games) programs take different directions based on constant feedback loops and evaluation data is collected as pupils use the program.
- Track how the US is developing new primary and secondary school standards <http://www.nextgenscience.org/>, which will be official in 2014.

Table 3: Some Similar Programs Worldwide.

(P=pupil; T=teacher; S=university students; C= coaches)

Program Name	Setting; visit duration	Ps ages/ max Ps per visit/ Ps per year	PRE and POST Materials and Training	Roles
mobiLLab, PHSG, St.Gallen, Switzerland Since 2009	Bring up to 12 experiments into classroom. Half day per class group. Each P does 3-4 experiments.	13-16/ 24/ 900*	PRE: One-day teacher training required; E-learning and question-development recommended. POST: -	Ps pairs conduct experiments independently with coaching from mobiLLab Cs. Ts sometimes participate during visit.
iLab, Paul Scherrer Institut, Switzerland Since 2008	Ps visit sound or vacuum laboratory in the morning; take a facility tour in the afternoon.	14-15**/ 24/ 4000	PRE: - POST: -	PSI scientists lead full group discussions about Ps independent lab work. Ts can assist with program but have no official role.
Morehead Science Center North Carolina, USA Since 1999	Inside bus at school Ps spend about 1.5 hours with experiments. ***	14-18/ 24/ school year 6000; summer 800	PRE: One-day Ts training required for module that comes to classroom. POST: -	Morehead instructor leads discussions about Ps independent lab work. Ts required by signed agreement to stay on bus.
CityLab, Massachusetts, US. Science center since 1991; mobile since 1998.	Bus typically visits school for a week. Ps work in bus for up to 8 hours, sometimes during several sessions.	12-19/ 24/ 4000 - 5000	Ts asked to use CityLab PRE and POST lessons.	Instructors work with Ts to customize experiments for Ps. Then Ps work in bus independently, sometimes sharing equipment. Ts may coach or observe.
ForschungsExpress Kiel, Germany 2005-2009	Experiments brought into 2 classrooms. Ps have 2 hours of either air, fire or plastic, and then switch.	9-11/ class size/ 2000	PRE: - POST: 5 th hour talk with teachers about how to continue the learning. Leave behind material that teacher can use.	Each P conducts experiments independently (no pairs). Scientist leaders guide the experiment. Two Ss come to assist Ps. Ts observe or participate in experimentation.
Humboldt Bayer Mobile Berlin, Germany Since 2010	Intro and pre and post work in classroom. Ps work in truck as a research experiment base.	11-15/ 15/ 1,800	PRE: - POST: Ps publish the results on the Internet on BM website.	Instructors introduce tools, program format. Then, Ps design and conduct experiments about their surroundings. Ss are coaches. Ts oversee.
MdBioLab Maryland, USA Since 2003	Bus stays at school for a week. Inside bus Ps spend 50-90 minutes with experiments. ***	13-18/ 32/ 10,000	PRE: Ts introduce the concepts and science before visit. POST: Recommend extension activities.	Instructors lead discussions about Ps independent lab work. Ts sometimes participate or lead discussions.
Lab in a Lorry United Kingdom Since 2005	Inside bus at school Ps spend about 1 hour with 2 of 3 available experiments.	11-14/ 18/ up to 24,000	PRE: T informed about visit content. POST: Provide leave-behind materials.	For each experiment, a volunteer scientist/ engineer coaches Ps. Ts observe and manage.
Science on Wheels Several states in India Since 1999	Several visits to each participating rural school per year. Inside classroom or on school grounds.	11-17/ class size / 1.6 million (66 mobile laboratory vans)	PRE: Instructors work with Ts to find out what Ps need. POST: Leave 'Lab-in-a-box' with teachers for use when extending learning.	Driver and two instructors bring van to a school cluster base and deploy senior P instructors to give demos in classrooms. Ps observe and interact with experiments.

*expected for school year 2012-2013. **can adjust program for ages 12-20. ***experiments can also be brought into the classroom.

NOTE: PSI is not a mobile laboratory program, but a science center in Switzerland, interviewed in order to include an in-country comparison program.

Representatives from contacted programs shared several evaluation studies about mobile laboratories and one about pupils' experiences at a Swiss science center, the Paul Sherrer Institute. Pupil surveys focus on evaluating development of pupils' science interest, attitudes and knowledge. Some but not all program evaluations show an increase in pupil science interest, positive attitude and/or knowledge right after their mobile laboratory visit and most studies suggest that any gains generally decrease over the next weeks and months. Teacher surveys generally show high overall teacher satisfaction with mobile laboratories and their perceived impacts on pupils. For some studies, a hypothesis is clearly stated in the evaluation report or was offered during an interview.

Table 4: Descriptive Matrix of Mobile Laboratory Evaluations.

(TG=treatment group; CG=control group; H: hypothesis drawn from results; T=teacher; P=pupil)

Program	Sample Distribution (TG/ CG)	Timing/ Duration	Goals/ Questions	Results/ Hypothesis (H)
iLab, PSI, Switzerland Pupil survey (Gassmann 2012)	11,000/ -	Last part of PSI visit. Each year since 2008.	Seven questions about interest in and understanding of experiments.	80% Ps find experiments understandable and interesting. Found a significant correlation between pupils who understand experiments and those who find them more interesting. H: Familiarity and understanding support interest development.
MdBioLab, Maryland Pupil survey, teacher survey and interviews (Dowell 2011)	970/ --	Before and after lab visit. (1997-2011)	1-Test science knowledge and literacy, 2-Ask about attitudes towards science and careers, 3-Ask teachers about experience.	Ps showed knowledge increase, girls more, blacks less. Slight impact on interest and confidence in science or perceived usefulness of science. H: Greatest effect is on pupils who are unsure about their interest and ability; they become more confident with their competence to conduct experiment.
Lab in a Lorry, Great Britain, Pupil survey (Barmby 2005)	268/ 81	2 weeks before, 2 weeks after ML visit. 2005.	Ps science interest, perceived ability, attitude, future intentions. Also teacher and volunteer interviews.	Both TG und CG Ps' attitudes toward science declined, consistent with decline with Ps age. Ps and volunteers' found experience enjoyable and motivating. H: Incorporating more hands-on work in the classroom may have more lasting effect on Ss' attitudes, Ts' professional development.
Morehead Science Center, North Carolina, Pupil survey (Harden, personal communication, November 20, 2012).	~6000/ ~3000-6000	Before, after the mobile lab visit during school year. Since 2002.	Questions about biology for honors biology pupils.	In some classes P survey scores were about two times greater after mobile lab visit than before. CG pupils who experience the same lesson but not the lab showed a smaller performance improvement. It is difficult to discern between effects from our mobile laboratory program and other factors in pupils' lives.
CityLab survey of teachers who use mobile laboratories in the US & Hong Kong (Franzblau 2011)	Teachers of age 5-10: 48 11-13: 51 14-19: 75 / --	Online survey distributed in spring 2010.	What benefits do Ts attribute to their participation in MLs? What impact do Ts perceive that ML experience has on P learning, attitudes, behaviors?	Ts perceive that mobile labs successfully meet key goals of exposing Ps to advanced equipment and techniques, increasing Ps interest in science. Ts reported that P engagement, learning and retention were high, and rated mobile labs experience as better than other options such as museums, etc.
CityLab ML student survey Boston, Massachusetts*	540/ 123	2003	What is the impact of the CityLab and/or its mobile lab experience on pupils' attitudes about biotechnology?	Attitude gain for both TG and CG was small; however, Ps who visited CityLab or had a visit from its mobile lab developed a significantly more positive attitude than CG Ps.

6. Results: Research about Informal Science Learning Environments

An initial look at research and evaluation studies of informal science learning environments shows what pupil outcomes evaluators and researchers are studying.

What are they studying?

Evaluators and researchers are studying a number of pupil parameters related to informal science learning programs and environments and the mind map in Figure 5 shows many of them. The five main parameters, shown in green – interest, attitude, knowledge/performance, career and perceptions of science - are in three-dimensional boxes to represent a temporal dimension seen in some studies. There are overlaps between studies with respect to how some parameters are defined. For example, some studies investigate the “affective aspect of interest,” referring to a good mood and positive experience, which is described by other studies as “science attitude.”

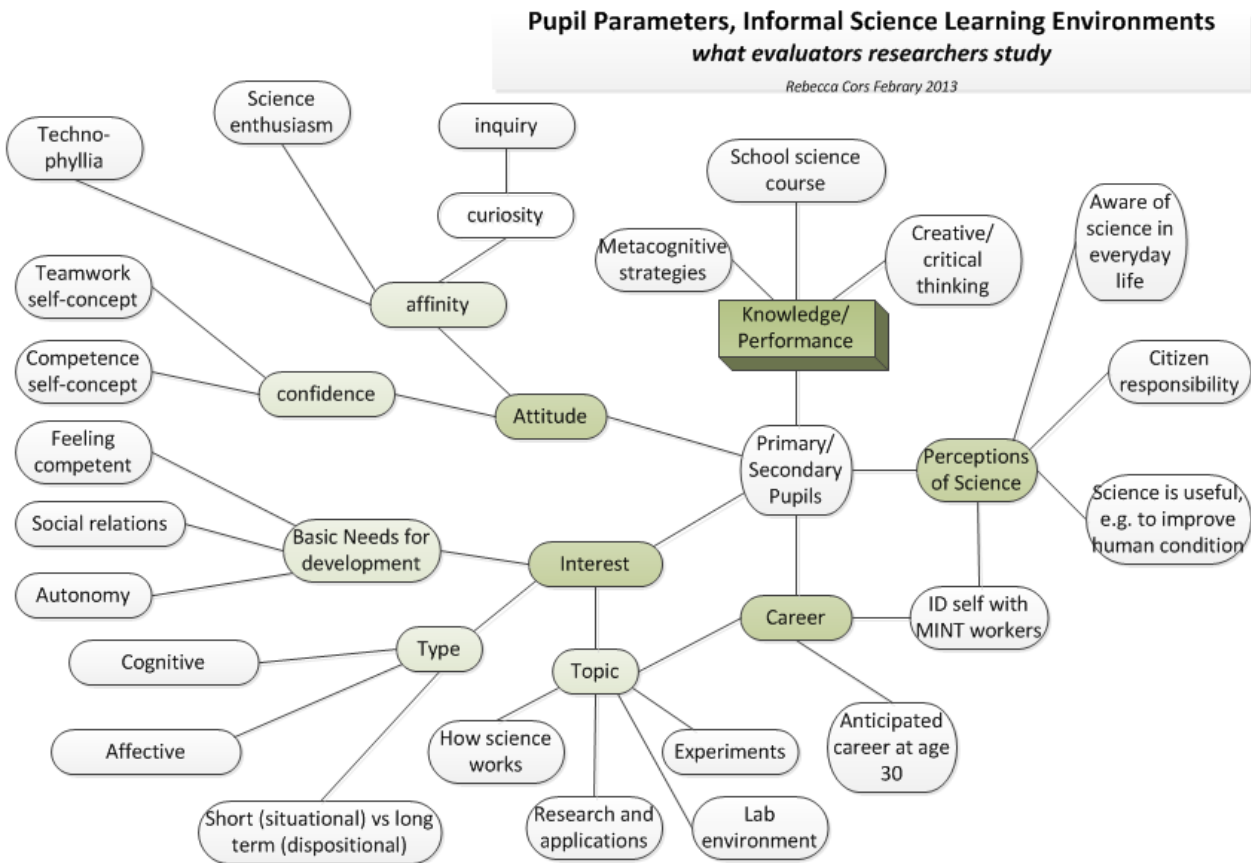


Figure 5: Mind map of parameters evaluators and researchers are studying.

Relevant research

The program evaluation questions in the left column of the table below are based on the mobiLLab program logic model (page 7). The column on the right shows related theories and studies identified during an initial review of literature, conducted following suggestions from interviewed educators and researchers and results from the search engine Science Direct, using key words from the questions in the left-hand column. These types of questions regarding pre-visit and post-visit instruction, teaching and learning approaches, novelty effect, teacher and pupil self-concept, cognitive and affective needs for science interest development, and choice and self-regulation have been explored for classroom and museum environments. However few, if any, studies have investigated these types of questions at science centers and mobile laboratories.

Table 5: Possible questions for a mobiLLab evaluation with related theories and studies.

(P= Pupil; T= Teacher; ML= mobiLLab; H=Hypothesis; S&T=Science and Technology).

Question Areas	Theories/ Studies
<p>PRE-VISIT ACTIVITIES</p> <p>Q: What type of pre-visit activities promotes pupils' S&T interest development through a mobiLLab experience?</p>	<p>Type of preparation. Jarvis (2005) found that <i>types</i> of preparation/ post activity are important. When pupils know what to expect they show a decrease from pre-visit anxiety.</p> <p>Cognitive Load Theory. Kirschner (2006) explains that the free exploration of complex, unfamiliar (without preparation) environment may generate a heavy working memory load that hinders learning.</p> <p>Novelty effect (Falk 2011) Pre-visit orientation suggestion offered (p. 153) to moderate novelty effect.</p> <p>Pre-visit activities and place/timing in curriculum were main influencers on field trip learning. (Orion 1994)</p> <p>Three Factors Model Orion and Hofstein as summarized by Eschach (2007) describes how pupils' previous knowledge; previous acquaintance with topic affect learning.</p>
<p>TEACHING AND LEARNING APPROACHES</p> <p>Q: What teaching and learning approaches promote pupils S&T interest development and learning during a mobiLLab visit?</p>	<p>Scaffolding: To optimize attitudinal and cognitive gains, teachers have to provide support and "scaffolding" between pupils' existing concepts and the exhibits (Jarvis 2005).</p> <p>Classroom contextual factors such as authentic tasks or projects without one right answer that allow longer periods of time for completion promote cognitive activity, conceptual change and learner motivation (theory from Pintrich et al. 1993; Alsop et al. 2005 employed by Milner (2010)).</p> <p>More hands-on science activities in classroom would promote lasting interest, positive attitude (Barnby 2005).</p> <p>Alternative (misconceived) theories. (Anderson 2000) for informal learning events, pre and post-test activities not only support the pupils' development of scientific concepts, but also detect and respond to alternative (incorrect) personal theories .</p> <p>Assimilation. Most learning involves continuously piecing together new bits of information into existing bits of thinking (Piaget).</p> <p>Teacher approaches to science teaching and learning greatly affect pupil learning outcomes (Kuhn 2010).</p> <p>Connections to out-of-school learning affect science learning outcomes (Tran 2011).</p>

<p>NOVELTY OF EXPERIMENTS AND LAB ENVIRONMENT</p> <p>Q: Do differences in experiment types play a role in how pupils' S&T interest develops through a mobiLLab experience?</p>	<p>Novelty of technology can promote interest (Sandifer 2003). Open-endedness and technological novelty helped account for a significant portion of the variance in average holding time per museum exhibit.</p> <p>Familiarity supports interest development PSI science center (Gassmann 2012).</p> <p>Novelty effect (Falk 2011) Novelty of place seems to cause anxiety, nervous behavior in children (p. 50).</p> <p>Novelty, pre-knowledge, pre-visit activities and timing in curriculum were main influencers on field trip learning. (Orion 1994)</p>
<p>AFFECT and COGNITIVE TRIGGERS FOR INTEREST DEVELOPMENT</p> <p>Q: What affective and cognitive factors support pupils' S&T development of interest during a mobiLLab visit?</p>	<p>Person-Object Theory of Interest development (Krapp 1999); tested for science centers by (Glowinski 2011), (Pawek 2009), others.</p> <p>Basic emotional needs for interest development are competence, autonomy and social relatedness (Deci 1991).</p> <p>Largest effect of mobile lab is on pupils who are unsure about their interest and ability; they become more confident with their competence to conduct experiment (Dowell 2011).</p> <p>Interest cross-reference Pupils show greater interest development if cross-references are made to pupils' interest (Hoffmann et al 1997 as reported by Krapp (Krapp 1999).</p> <p>Valuing object of learning supports cognitive need for interest development (Krapp 1999).</p> <p>Control-value theory of achievement emotions (Pekrun 2006).</p> <p>Learning success level during a museum visit was explained by previous interest levels (Falk 2005).</p>
<p>TEACHERS' S&T SELF-CONCEPT, ATTITUDE; PUPILS' SELF-CONCEPT</p>	<p>Influence of teachers on students' attitudes to school science, subject choice (Osborne 2003).</p> <p>Four-Phase Model of Interest Development (Hidi 2006) proposes that pupils shift between phases of learning and must go through earlier phases to reach later phases. Renninger (2009) suggests support for development of interest should be tailored to pupils' current phase of disciplinary interest and to their <i>age-related identity</i> with the discipline.</p> <p>Teacher typology (Jarvis 2005) teachers' personal interest was among important factor influencing children's attitudes.</p> <p>Teacher interest perceived by pupils relates to pupil's motivation and learning (Long 2006).</p>
<p>CHOICE, SELF-REGULATION</p> <p>Q: How do pupils choose between learning goals and well-being goals during a mobiLLab visit and how does this affect their S&T interest development?</p>	<p>Teaching style, objectives (Högström 2010). Teacher objectives – stated and implied by interactions – highly influence what pupils think is important to learn.</p> <p>Dual-processing self-regulation model (Boekaerts 2005; Boekaerts 2007) describes how learning goals interact with well-being goals.</p> <p>Self-determination theory: If intrinsically motivated to learn, pupils perform better and show more interest. If valued enough, people strive to perform well and to take an interest in activities they may find intrinsically uninteresting (Deci 1991).</p>
<p>LEARNING EXTENSION</p> <p>Q: Does extension of mobiLLab concepts in a follow-up classroom lesson help pupils sustain their gains in S&T interest and knowledge?</p>	<p>Learning is cumulative (Rennie 2003) : Informal science learning research needs to consider learning as a cumulative process (as part of the 6 issues recommended for out-of-school learning research).</p> <p>Teacher typology (Jarvis 2005) follow-up was among important factors in influencing children's short- and long-term attitudes.</p> <p>Integrating out-of-school and classroom learning. (Glowinski 2007) . Immediately after and also 12 weeks later, pupils with higher science interest gains correlated with teachers who integrated lab learning with classroom learning.</p>

7. Discussion and Recommended Targets

The background investigation revealed “hot spots” (underlined in the discussion below), which are areas of greatest concern and possible impact for mobiLLab program improvements. What have we learned so far about these program aspects and what target actions, evaluations and areas for further inquiry should guide mobiLLab program development?

Pre-visit Activities

Teachers embedding mobiLLab in their curriculum is the top concern for the mobiLLab team, in particular pre-visit activities (pupils reviewing elearning and preparing their own questions), which they observe greatly affects how engaged pupils are in mobiLLab experimentation. Teachers who participate in the mobiLLab program describe different approaches for conducting pre-visit activities. Some teachers spend three hours of classroom time to introduce the experimental posts and ask pupils to review the elearning tutorials on their own time, while others spend up to eight hours of classroom time and ask pupils to prepare written justifications for their experimental post requests, review the elearning during class time and prepare their own questions for each post. *How can we motivate teachers to use the pre-visit activities that mobiLLab recommends?*

Some research studies emphasize the importance of the *type* of pre-visit activities (Kubota 1991; Jarvis 2005; Eschach 2007; Dohn 2010), pointing to the question, *What pre-visit activities best support pupils' engagement in mobiLLab experimentation and pupils' knowledge and interest gains?* Some participating teachers invent their own pre-visit materials (some has been collected), providing some specific ideas we can draw from. Other studies suggest effective pre-visit teaching and learning approaches including scaffolding, employing authentic tasks, pre- and post-tests/classroom assessments that enable teachers to better understand pupils' existing conceptions, employing surprising and little-known facts to spark interest, appreciating pupil efforts and supporting their exploration of their own ideas, and helping pupils make connections between in and out-of-school experiences.

Post-visit Activities

Also important to mobiLLab team members is how post-visit activities could promote pupil retention of science and experimenting interest. Some participating teachers develop their own post-visit materials, indicating teachers could inform investigation and action here. While there are handful of existing studies about pupil interest and knowledge retention in the weeks and months after an informal science learning experience (Jarvis 2005; Pawek 2009; Glowinski 2011), the results of these studies are often inconclusive. *How can we explore the relation between teachers integrating extension lessons into their curriculum and pupil retention of knowledge and interest gains?*

Action Target: Drawing from experience and examples from other programs and studies, optimize pre-visit training and resources for teachers.

Evaluation

Target: Evaluate optimized pre-visit teacher training and classroom activities in relation to 1) pupil's engagement in mobiLLab experimentation, 2) pupils' interest and knowledge gains 3) pupil retention of interest and knowledge gains and 4) teacher motivation to employ recommended pre-visit activities.

Inquiry Target: Explore the use of pre- and post-visit activities by communicating with teachers who have developed such activities and by conducting a more exhaustive literature review.

Teacher Attitude

Thought by mobiLLab team members, participating teachers and also leaders from other programs worldwide to greatly influence the learning outcomes of pupils is teacher attitude and teaching approach. Teacher attitude and teaching approach as a key to improving learning outcomes is not a new idea and as early as 1966, the OECD (1966) asserted that "the teacher is the curriculum." To investigate this area, we need to answer the question, *What about teachers' attitude and teaching approach should we seek to better understand?* Results from other studies suggest that what pupils perceive as teachers' learning outcomes, teacher interest in science, whether pupils believe teachers are interested in science, whether pupils believe teachers effectively teaching science, and also teachers' preferred teaching and learning approaches (e.g. encouraging pupils self-construction of concepts, situated learning) affect science learning outcomes.

Evaluation

Target: Drawing from experience and other studies, identify teacher attitude and teaching approach factors thought to affect pupils' learning outcomes and evaluate this relation.

Coaching

Questions surfaced during the background investigation about the assumption that student coaches are trained to properly coach pupils in science and inquiry. While student coaches receive training on experimental post equipment, some report lack of confidence in working with equipment. The mobiLLab team would like to know, *How well does the training for coaches prepare them to coach pupils in experimentation, science and inquiry at mobiLLab posts?*

Action Target: Starting in the Fall of 2013 student training will provide instruction about how to apply inquiry-based strategies while coaching pupils at mobiLLab experiment posts.

Evaluation

Target: Development of a student survey is underway. It is slated to be distributed to students who coached at mobiLLab school visits in the 2012-2013 school year.

Experiment Types

Questions about the assumption that experiment posts are designed to promote pupils' engagement and inquiry also came to light. MobiLLab was designed based on studies about promoting pupil interest in natural science through experimentation. At the same time, observations from the mobiLLab team indicate that the different ways in which the experimental posts are designed promotes varying pupil behavior at the posts. Moreover, experimental posts are primarily about chemistry and physics, two science topics shown to be more interesting to boy than girls (Buccheri 2011; Bybee 2011). *How do the characteristics of*

mobiLLab experiments relate to how engaged pupils are at their posts? One possibility is to develop a typology for experiments, following the example of Sandifer (2003), who found that open-endedness and technological novelty of exhibits explained the amount of time that museum visitors spent at each exhibit. The approach for developing experiment typologies, which is reported to require substantial resources, should be more clearly defined.

Inquiry Target: Learn more about methods to, and resources required to, categorize mobiLLab experiments in order to develop an experiment typology. Through such a typology, mobiLLab experiment types can be related to 1) pupil tendency to select these experimental posts, 2) pupil behavior at experimental posts and 3) pupil interest and knowledge development.

Technophilia

Promoting pupils' positive attitude about high-technology science experimentation is the core goal of the mobiLLab team, who describe their mission as promoting "technophilia" (in both pupils and teachers). Somewhat related, it seems, is the goal of many other mobile laboratory programs to cultivate science literacy, or a sense of citizen responsibility, among youth, a priority also reflected in PISA testing (Bybee 2011). Moreover, the *image* of studying and pursuing careers in science and industry is unattractive to youth in Switzerland, many of whom believe that if they are not 'gifted' in the sciences, then efforts to study science are not really worthwhile. *How could mobiLLab improve the image of science and technology for youth? What seems to spark and fuel pupils' sense of possibility and interest?* Some programs, including mobiLLab, employ student coaches so pupils can identify science and technology experimentation with people who are near their age.

How can we track whether mobiLLab and any changes in teacher training, pre- and post-visit activities, coaching and experimental post design are effective in promoting development of pupil interest in science and technology? Some studies have explored pupil factors such as perseverance, confidence, effort, self-efficacy, affect, object/ task value, anxiety and reengagement as triggers for situational development and also as signals of development a more lasting individual interest. Other clues come from leaders of similar programs, who are finding that pupils who understand experiments at PSI lab in Switzerland tend to find them more interesting and pupils who are unsure about their interest and ability profit the most from MdBioLab.

Inquiry Target: Further explore the reasons that science and technology have a poor image among youth in Switzerland. Then, drawing from experience and other research, identify strategies thought to improve pupils' image of science and technology. Consider how these strategies could be integrated into the mobiLLab program and evaluated for effectiveness.

Evaluation

Target: Based on experience and existing studies, identify indicators for pupil science and technology interest and knowledge development through a mobile laboratory experience. Use these indicators to evaluate the program's effectiveness, particularly with respect to the influence of factors such as teacher attitude, pre-visit activities and experiment type.

8. Future Research

Results from studies about programs similar to mobiLLab suggest that these informal learning experiences result in little or no change in pupils' learning outcomes and that these changes often fade after a month or two (Barmby 2005; Jarvis 2005; Pawek 2009; Dowell 2011). Future studies should dig deeper into factors, listed below, identified through our interviews and literature review that are thought to influence pupils' learning outcomes. Three of these factors - teacher disposition, links to classroom learning and experiment type - were also named by the mobiLLab team as areas of greatest concern and leverage.

- Novelty as unfamiliarity (Orion 1989; Orion 1994; Falk 2011; Gassmann 2012) and as attractiveness (Dohn 2010; Förster 2010)
- Exploratory behavior at experiments/ exhibits (Falk 1978; Kubota 1991)
- Teacher disposition: S&T interest, teaching approach (Long 2006; Kuhn 2010)
- Links between informal and classroom activities (Orion 1994; Anderson 1999; Pawek 2009; Tran 2011)
- Differences in experiment types (complexity; moving parts) (Sandifer 2003)
- Place of mobiLLab in the semester plan (curriculum) (Orion 1994; Eschach 2007)
- Perceived purpose of the mobiLLab visit (Högström 2010)
- How pupils are engaged or on-task at exhibits/posts (Boekaerts 2005)
- Pupils who have before-visit low or medium interest (Pawek 2009; Dowell 2010; Glowinski 2011)
- Pupils' ability to relate science of experiments to everyday life
- The quality of instruction (Pawek 2009; Glowinski 2011)
- Keeping the science simple and allowing pupils to focus on the experimental process
- Asking pupils to take responsibility for their own learning
- Having pupils work independently of instruction and, some suggest, without a peer partner
- Presenting experiments as real-world problems
- Holding discussions about pupils' questions before or after experimentation
- Giving class groups more than one experience; talented pupils can take on a mentor role

Many studies of informal science learning environments have measured pupils' learning outcomes as changes in cognitive (knowledge) and affective (emotional) aspects of science interest. The theoretical basis for most of the research-based studies has been Deci and Ryan's Self Determination Theory (1991) or Krapp's (1999) Person-Object Theory of Interest. However, for pupils around the world, their "science interest" depends upon the specific science topic. While some pupils are interested in sciences that are more often related to technology, such as physics, others are more interested in "low technology" sciences, such as biology, and these topical interest differences sometimes correlate with gender (Buccheri 2011; Bybee 2011). Moreover, program leaders wonder how studies can discern between effects of their programs and other factors in pupils' lives. The high-technology mobiLLab, with experiments that relate to several different science topics and with a core program outcome of promoting 'technophilia,' would benefit more from an investigation designed with these distinctions in mind.

Finally, as some studies show (Barmby 2005; Jarvis 2005; Franzblau 2011), those who operate and provide instruction for informal science programs, and also participating teachers, can offer important insights into factors that promote positive changes in pupils' learning and attitudes. Studies can produce more meaningful, useful results when they, to the extent possible, develop goals and theory produced in collaboration with program staff and participating stakeholders and plan to produce results that can guide program development (Taylor-Powell 2003; Hussar 2008; Patton 2008).

9. Appendixes

Additional Teacher Comments

Teacher comments regarding their ratings of how strongly national and cantonal education guidelines and programs influence teachers and pupils.

List 4: Teacher comments about their ratings of how strongly education national and cantonal guidelines and programs influence teachers and pupils.

- We would like to bring mobilLab to our school during the career choice process (2nd semester in 8th grade) in hopes of awakening pupils' interest in technical careers before they choose their apprenticeship.
- During the career choice process (8th Class) we hold interviews with parents and pupil to discuss the pupil's Stellwerk test results and performance against (cantonal) standards. Together we develop a targeted career path agreement, which is signed by parents, pupil and teacher.
- Stellwerk is increasingly central to career choice and getting a job. Many companies in industry, trade and commerce use it as employment criterion.
- Pupils do not learn their results for the PISA tests and therefore it has no impact on their career choice.
- While HarmoS and EDK standards don't affect us directly, our Lehrplan (cantonal curricula) are affected by them.
- TIMS is an older PISA test that the pupils take. It does not strongly influence pupils' outcomes.
- The biggest influence is the relationship between pupils and teacher.

Swiss education programs and guidelines

Cantonal Curricula (German *Lehrpläne*)

Up to now, official guidelines for secondary school curriculum in Switzerland have come from cantonal governing bodies for education. These cantonal curricula specify the topics teachers in each discipline should cover during the school year for each grade level. Currently the 21 German speaking cantons have started to work on one common curriculum, Lehrplan 21, for primary and secondary education. Once developed, each canton may accept or reject Lehrplan21 and, should they accept it, they can decide how to implement the standards.

HarmoS Competences and EDK Standards

The Conference of the Swiss Cantonal Ministers of Education (*Schweizerische Konferenz der kantonalen Erziehungsdirektoren (EDK)*) is the national governing body for education in Switzerland. Since 2001, the EDK has organized a strategic initiative to harmonize obligatory school curricula, called *HarmoS*. A core goal has been to develop countrywide standards and a model of competences has been developed for the four disciplines first language, foreign language, mathematics and natural science. For natural science, for example, the two core aspects are 1) skills in scientific work such as *Explore, Investigate or Conduct an Experiment* and 2) standard themes such as *Motion, Power and Energy*. Also included are recommendations for developing pupils' interest in the natural sciences and technology, their ability to explore and experiment, their ability to work independently and work cooperatively (teamwork), and encouragement for teachers to employ active, authentic approaches.

In 2011, based on these models of competences, the EDK has released set of national standards which pupils are supposed to achieve by the end of year 4, 8 and 11 (<http://www.edk.ch/dyn/12930.php>)

Lehrplan 21 (Teacher plan for the 21st century?)

The D-EDK, the national education governing body of the 21 German-speaking cantons of Switzerland, is developing the first common curriculum for K-11 school subjects for all 21 German speaking Cantons together. It may be presented for public consultation as soon as summer 2013. The curriculum is called *Lehrplan21*, which translates to mean “*Lesson Plan 21*,” which refers to a common curriculum for the 21st century and because there are 21 German speaking cantons who will be asked to adopt Lehrplan 21 for use in their canton.

PISA

The Program for International Assessment (PISA) is an international study that was launched by the OECD (Organization for Economic Co-operation and Development) in 1997. It aims to evaluate education systems worldwide every three years by assessing 15-year-olds' competencies in the key subjects: reading, mathematics and science. To date over 70 countries and economies have participated in PISA.

Stellwerk

In some Swiss cantons, pupils in secondary schools level 1 (*Sekundarschul 1*) must take the Stellwerk online test in their 8th and 9th years, ages 14-16, at school. It offers pupils an individual analysis of their aptitude in five subjects: Math, German, Natural Science, English and French. It was originally developed to enable businesses and industry to compare applicants during a hiring process.

Additional Notes from Interviews with Other Programs

List 5: Comments from other program leaders about what factors are most influential on pupils' engagement and science interest development.

- *Teachers*: what they do and their attitude towards science.
- *The truck* is an advertisement that the pupils are doing something new and interesting. This “visibility value” seems to bring some flash and excitement to the image of science experimentation. When accompanied by an authentic, high-quality experimentation program and science coaches who encourage the pupils to have fun, it shows that science can be “cool.”

List 6: Comments from other program leaders about working with pupils.

- Pupils need help connecting science theory from the classroom with science laws and applications. For this reason, instructors at the sound lab at PSI begins the visit by talking about bat sonar, sensors for backing up car, distance measurement with tools, ultrasound wave that show the image of an unborn baby in the womb,, and so on.
- Keep experiment level simple.
 - Simple science experiments use commonly available equipment that teachers can use later in their classroom to continue experiments.
 - Simple experiments allow more time for pupils to develop questions, hypothesis and experiment designs.
- Pupils who are unsure or have medium interest have the highest potential to become curious and develop interest in and confidence with technology and science experiments.
- It is important for pupils to work on their own.
 - When pupils only follow their partner and then they don't build their confidence.
 - Give pupils the responsibility for their own learning.
- It's important that pupils have products that they can bring home.
- Teachers believe pupils find our program's activities interesting because the science is linked to the real world.
- It is difficult to discern between effects from our mobile laboratory program and other factors in pupils' lives.
- Humboldt-Bayer Mobile developed their program format based on how pupils need more practice independently formulating their own questions and designing their own experiments.

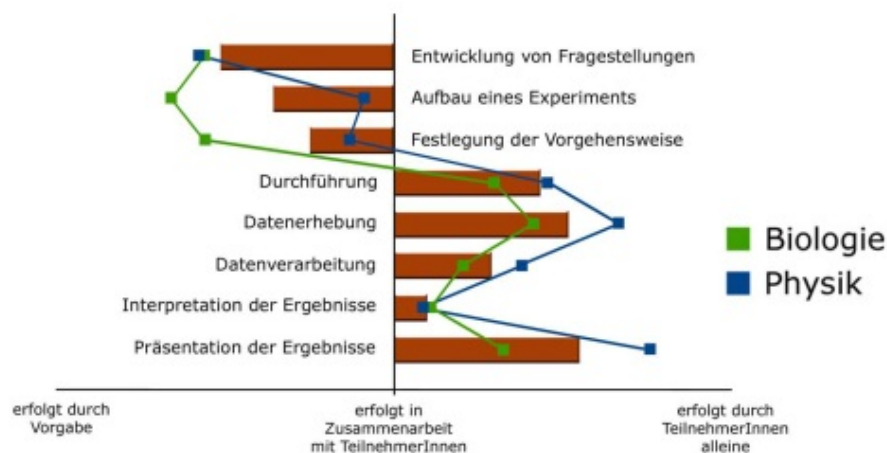


Figure 6: Pupils studying biology and physics have the least amount of practice with formulating their own questions and designing experiments (Dänhardt 2009).

List 7: Comments from other program leaders about teacher training and employing science coaches for mobile laboratory deployments.

- ForschungsExpress thinks their teacher advising and training is better accepted because instructors are not teachers or professors.

- MdBioLab uses primarily instructors who have just finished college in what they call a Near-Peer-Mentor model, which suggests that younger coaches can sometimes make a better connection with pupils.
- Some programs (MdBioLab and Humboldt-Mayer Mobile) employ young coaches, rather than scientists on a part-time or full-time basis to schedule visits, drive to the school, set up equipment, and guide group experimentation. They train the assistants in presentation skills, laboratory techniques, and inquiry learning approaches.
- Hold discussion with teachers after visit about extending learning.

List 8: Comments from other program leaders about controlling program costs.

Many programs talked about the high cost of maintaining a mobile laboratory. Solutions they described were

- Employ a students or entry-level workers to coordinate and staff mobile laboratory visits.
- Conduct simple experiments that require everyday material (ForschungsExpress).
- Develop computer games (MdBioLab is developing SeriousGames), which has high up-front costs but much lower maintenance costs. The game-based learning takes different directions based on constant feedback loops and evaluation data is collected as pupils use the program.

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