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Report on the evaluation of the education program Experimento | 8+

Results, recommendations and implementation of the recommendations

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Foreword

From 2018 to 2020, Siemens Stiftung decided to commission an evaluation of its Experimento program for elementary schools. The aims of the evaluation were to assess the quality, impact, and usage of the program in greater detail. The Chair of School Pedagogy at Technische Universität Munich and the Institute for Biology Education at Ludwig-Maximilians-Universität Munich were commissioned to run the evaluation. This report summarizes the key evaluation findings and presents the recommendations derived as a result. As an intermediate step, the aim of the evaluation is to enable Siemens Stiftung to further develop and refine Experimento.

Evaluation is the systematic examination of use and/or value of a subject based on empirical data. (DeGEval, 2016, p. 66). The evaluation "should serve to assess the quality of pedagogic interventions, education institutions, and entire education systems. Ideally, the evaluation should initiate interventions or optimization efforts of what has been evaluated" (Lüftenegger, Schober & Spiel, 2019, p. 518). The procedure and questions for the evaluation were summarized in a set of guidelines (Lankes & Haslbeck, 2021).

In total, five evaluation studies were conducted:

1. Analysis of materials and documents from Experimento | 8+
2. Impact of the training program Experimento | 8+ on knowledge acquisition and attitudes of teachers
3. Use of training materials/experiments and satisfaction of teachers
4. Implementation of Experimento | 8+ in teaching
5. Impact of Experimento | 8+ on skills and motivation of students

The results are highly nuanced and provide relevant recommendations for improvements. The results from **Study 1** show that the topics covered have a high level of conformity with German curricula and international standards. A high level of subject relevance and a high level of conformity with a range of scientific methods and approaches was also identified.

The results from **Study 2** demonstrate very positive effects from the training on the personal attitudes and beliefs of teachers. While methodical knowledge largely already exists, an even greater emphasis should be placed on didactic expertise in the training.

The results from **Study 3** show that there is a very high level of satisfaction with the materials among teachers. Accordingly, these materials provide a solid foundation for teachers to carry out the experiments adequately, as becomes clear in **Study 4**. Students, however, could be given somewhat more freedom to experiment.

Students benefit from Experimento both in terms of skills and in motivation, as is demonstrated by **Study 5**. Children in Experimento classes assess their scientific self-concept to be at a significantly higher level than children in the control group. Girls in the Experimento group are significantly more interested than girls in the control group. The use of the Experimento program is associated with significant differences in the motivational conditions for students. They are more interested in science and are more confident and willing to try things out. These are good preconditions for the creation of long-term, sustainable scientific competencies.

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For each individual study, there are recommendations for how to increase the quality of the Experimento education program. These recommendations have been addressed within the context of digitalization, accelerated by the coronavirus pandemic, and have been fully implemented in a new version of the training involving a blended learning format. This development was undertaken by the Chair of Education and Educational Psychology at the Faculty for Psychology at Ludwig-Maximilians-Universität Munich.

In the following, the results of the evaluation are summarized and the individual steps for the review are explained. In concluding, the implementation of the recommendations from the evaluation are presented again in summary form.

Munich, September 2021
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Evaluation studies and recommendations

As part of the evaluation, a total of five individual studies were conducted. To begin with, the relevant documents and materials developed for the education program to support experimentation in elementary schools are examined in the **first study**. The **second study** looks at the training program itself. The aim of the training is for teachers to acquire methodical and didactic knowledge. In addition, attitudes and the motivation to conduct experiments in classes are relevant. After all, the later use of experimentation materials in teaching is of great importance, given that it is the underlying educational goal of the training program. This question is explored in **Study 3**. The use of Experimento in the classroom by teachers is the focus of **Study 4**. Finally, in **Study 5**, the impact of experimentation on students is investigated, particularly in terms of their experimentation skills and on their motivational attitudes.

Study 1: Analysis of documents and materials for Experimento | 8+

Objective:

The purpose of the analysis of the documents and materials is to determine to what extent these support the educational goal of Experimento | 8+, i.e. to integrate inquiry-based learning into teaching.

Scope:

Guidelines for teachers and pupils for a total of 43 individual experiments covering 17 topic areas overall, in the areas of energy (5 topic areas), environment (6 topic areas), and health (6 topic areas)

Method:

Content analysis by two experts

Study 1a: Support of basic science education

Question:

To what degree are subject relevance, diversity in scientific methods and approaches, and a skills-based focus implemented as conditions for basic science education?

Results:

Subject relevance: The subject relevance of the program was reviewed against German curricula and the basic concepts defined in education standards. International standards (TIMSS) were used to give an international perspective.
The analyses showed that the topics and concepts that were used offered a high level of conformity with German curricula and basic concepts and an even higher level of conformity with international standards. In addition, the materials extend beyond the curriculum requirements by providing options for engaging with science – also outside the classroom in workgroups and projects.

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Range of scientific methods and approaches: All scientific methods and approaches that are relevant in secondary schools are included in the handouts and guidelines for both teachers and students. Rightly, two groups of approaches that form the fundamental basis for scientific experimentation are given the greatest attention: Behind each question, behind each experiment there is an observation or insight that needs to be carefully monitored during each experiment. To continue working with the observation, it is written up or recorded. Comparison and ordering activities that are also key to experimentation, as preliminary skills, are also well represented. Less common are the measurement and variation working methods.

Competency orientation: The starting point for evaluating the competency-based orientation of the material was the competency model from the German education standard. The handout for educators formulates a number of goals for each topic that are assigned to the four areas of educational standards. The teaching of scientific knowledge is the focus of many of the goals. In addition, the approaches and methods listed above are also mentioned as goals in many of the topics. Less frequent are goals that refer to evaluation, e.g. critical interaction with scientific fundamentals, or to the competency of finding and exchanging appropriate and correct information (communication).

Revision: During the revision of the guidelines for experimentation, this point was addressed in the "Evaluate and reflect" research step. In this step, there is now a subitem called "Reference to background". Within this sub-item, the aim is for the initial problem to be addressed and discussed, thereby creating space for critical reflection and evaluation of the experiment or experimentation. In addition, a dedicated module on value formation was created, which also focuses on the aspect of evaluation and reflection.

Study 1b: Content preparation of materials

Question:

To what extent are the materials complete and comprehensible in terms of the subject background? To what extent is there relevance to the curriculum? To what extent are the experimentation materials designed in a user-friendly manner (usability)?

Results:

Completeness and comprehensibility of the subject background: The analyses showed that the subject background is fully covered for all experiments in Experimento | 8+ and is presented in a way that is readily comprehensible for teachers.

Relevance to the curriculum: With regard to the concepts covered in the experiments, there is a high level of conformity with the contents of the German elementary school curricula. Teachers can meet selected targets from the curriculum by using the program and do not have to make additional time available.

User-friendly design of the materials All materials provided comply with safety requirements. With a few exceptions, all materials required for the experiments are listed in full. All materials that need to be obtained are easily available, the time requirements are listed appropriately for nearly all experiments.

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Study 1c: Implementation of the necessary conditions for effective science education.

Question:

To what extent is a phenomenon-based, problem-based, or student-based approach implemented, as a condition of effective science education?

Results:

Phenomenon-based approach: Linking scientific concepts with everyday phenomena in teaching is a suitable method for helping pupils to understand, comprehend, and apply scientific concepts. The analyses show that there is a consistent phenomena-based approach in almost all experiments. Most topics mention several phenomena for each experiment that elucidate and make the concept visible. In further developing the program; suitable everyday examples should be integrated into all experiments.

Revision: As part of the revision of the training, the puzzle component of “Identify problem or phenomenon” was added to the research cycle. The research cycle now includes stories from the daily lives of pupils for each experiment. The instructions for teachers and students have been fully revised to take this change into account.

Problem orientation: At the beginning of the cognitive process, there is normally an observation or problem that raises a question. In Experimento | 8+, there is a short text in the instructions for students at the beginning of each experiment that aims to fulfill this function. In order to design the scientific cognitive process that guides students from the phenomenon to questions and hypotheses in a rigorous and compelling manner, it would be desirable to formulate all introductory texts concisely and consistently, based on a problem or question.
Revision: The puzzle component “Identify problem or phenomenon” has been added to the instructions for experiments for both teachers and students. In this component, everyday stories are outlined that justify the subsequent experiment and which are closely based on the relevant research question. If necessary, the research questions and hypotheses have also been adapted to increase the rigor of the content.

Student orientation: The discovery-based approach is a fundamental pillar of the Experimento education program: Pupils should receive a wide range of opportunities to engage with the experimentation materials themselves and to actively carry out as many steps in the cognitive process themselves as possible. The structure of the individual experiments in the research cycle supports this process. The children are guided through the cognitive process on a step-by-step basis. In almost all experiments, they are first asked to observe and examine something closely. Both the instructions for teachers and those for pupils offer a range of sample questions for each experiment, thereby supporting an inquiry-based approach to teaching. In addition, the instructions for pupils encourage them to activate their prior knowledge, formulate hypotheses and to draw conclusions from the experiments. The experiment conduction process normally consists of a set of precise, step-by-step instructions. Only when it comes to the experiment planning would more independent activity be preferable. Elementary teachers often feel uncertain when conducting experiments in class and for this reason they prefer precise, step-by-step instructions. But if we want to empower students to experiment independently and freely in the long-term, it will be necessary to give them the opportunity to check their hypotheses themselves, based on targeted questions and

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concept-based hypotheses (which may vary with the use of variable control strategies). In this context, prescribing strict instructions that need to be followed step by step will not suffice; scope to take action and make decisions is called for here.

Revision: As part of the training program's blended learning concept, the second day of in-person training requires teachers to address how they would carry out the experiments with the students in didactic terms when designing specific lesson scenarios. In this process, there is scope for a wide range of different approaches, in which options are also developed for experiment planning to be handled more decisively by pupils themselves.

Implementation of recommendations from Study 1

The suggestions for improvement from the first study were fully addressed and implemented. The current research cycle was expanded to include the "Identify a problem or phenomenon" element, which means that this aspect has been added to all instructions for educators and pupils. This will allow the experiments to be linked more closely to everyday problems. The questions were also changed accordingly in order to increase rigor and relevance. In addition, the reference to the background story has been integrated into the instructions for teachers in the "Evaluate and reflect" research step, in order to encourage a discussion on the extent to which the experiment has contributed towards answering the initial problem. In this section, there is room for reflection and evaluation. In addition, a dedicated digital module on value formation has been created, in which the focus is on the critical reflection and evaluation of scientific problems. In the training, particularly on the second in-person day, a major emphasis will be placed on the didactic implementation of experimentation. This component can also be used to address options for free variation and for use of variable control strategies in teaching.

Study 2: Impact of the training for Experimento | 8+

Objective:

The aim of the second study was to assess the training in terms of the knowledge imparted (methodical and didactic expertise) and to assess the personal attitudes and beliefs of the teachers. Methodical expertise refers to experiments being conducted adequately. This includes knowledge about how hypotheses are formed and how their verifiability is identified, how experiments are planned and how the set-up of an experiment is assessed to ensure it make sense, and how dependent and independent variables are distinguished and how data is measured. Specific skills related to this include observation, the independent formulation of questions and hypotheses, measurement, comparison, categorization, and ordering, through to documentation and interpretation of the results.

Didactic knowledge refers to methods for explaining scientific concepts in a way that is easy to understand (e.g. with models) and where one can observe them in nature (phenomena). Ideas, problems, and alternative courses of action for how to guide pupils on a step-by-step basis through independent, free experimentation on a certain topic is part of didactic knowledge. In addition, didactic knowledge includes prior knowledge, difficulties, and students' misconceptions. The training has particular significance in terms of the didactic self-concept of the teachers. As this is a crucial precondition for actually being able to conduct experiments in classes, it was a major goal of the training. The perception of science and the interest in scientific phenomena is important in this respect.

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Questions:

1. To what extent does the training help to promote the knowledge (methodical and didactic expertise) of educators, in terms of an educational program?
2. To what extent does the training help to support the personal attitudes and beliefs of teachers?

Method:

Pre/post-test design: Survey of teachers before and after the training

Tools used:
1. Self-developed knowledge test on methodical expertise (knowledge about forming hypotheses, planning experiments, assessing data) and on didactic expertise (knowledge about students' difficulties and misconceptions in the sciences, strategies for model formation, biology-related phenomena on the topic of breathing and physics-related phenomena on the topic of electricity)
2. Questionnaire to record personal attitudes and beliefs (on the didactic self-concept, on the image of science and on interest)

Sample: 82 primary school teachers, mainly from the Year 3 and 4 Levels

Results:

Question 1: Acquisition of knowledge

The results of the pre-tests show that the teachers come into the training with very different levels of prior knowledge, both in terms of methodical and didactic expertise, which needs to be seen as a major challenge for the design of the educational program in the training courses.

Acquisition of methodical expertise: The training courses tend to lead to a growth in methodical knowledge about the experimentation method. The fact that the findings are not significant was to be expected, given the short intervention period, but in the case of teachers it was also a result of the fact that many participants already had pre-existing, underlying methodological expertise. Most are aware of the steps in the cognitive process, they can recognize the verifiability of hypotheses, and they can assess the structure of an experiment to ensure it makes sense. They can also identify the questions relating to this and distinguish between dependent and independent variables.
In terms of potential development, this means: the level of methodical expertise could be increased for teachers. As the cognitive process is already largely familiar to teachers, partial aspects of these could be covered in more depth in the training, using various experiments as examples, especially from a didactic perspective (see below).

Revision: This recommendation was followed for the blended learning concept in the training. As a key component of the training, the research cycle is taught in several stages. While teachers become familiar with the research cycle during the digital preparation phase, it is demonstrated using a sample experiment in the first in-person phase. In the online application, the research cycle is then covered in greater depth and is expanded with numerous other relevant aspects of methodical and didactic expertise. In the second in-person phase, what has been learned is transferred to specific teaching scenarios. Here as well, the focus is on methodical and didactic content.

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Acquisition of didactic expertise: Didactic expertise could change more as a result of the training. The teachers already knew before the training about the use of the models. Little changed as a result of the training. The knowledge about the use of electricity and breathing-related phenomena showed bigger gaps in the pre-test; the training led to increases in knowledge for a number of teachers. Knowledge about handling students' misconceptions was the least developed area in the pre-test. To date, the training has not been able to close these gaps.

Revision: As mentioned above, a training program that imparts this knowledge at various levels of difficulty using a blended learning format was developed to improve methodical and didactic expertise. Particularly on the second in-person day of training, didactic expertise is emphasized. In addition, authentic video clips from teaching in the digital learning phase demonstrates methodical and didactic knowledge by way of an experiment.

Question 2: Attitudes and beliefs

Didactic self-concept Following the training, the teachers rate their self-confidence in their own abilities at a significantly higher level than in the pre-test. This means the inclination, willingness and likelihood to conduct experiments in teaching and to offer them as learning opportunities has increased. A crucial factor behind the increase in self-confidence is the experience of "being able" to do something. The teachers' own activities, but also their own goal-driven research using questions, hypotheses, experiment planning and implementation play a considerable role in the training, which aptly explains these findings and is an argument for why they should absolutely be retained.

Image of science: Most teachers tend to have – in line with modern views – a constructive, open view of the sciences. Most teachers – with some exceptions – perceive science as having a medium to high level of personal importance and believe that science currently plays an important role for them. As expected, interest in biology is rated more highly than that in physics.

Interest: Ultimately, feedback from participants shows that the training sessions have piqued or boosted their interest and enjoyment in science. In general, everyone involved was very satisfied with the training, praising the speakers and the entire organization and expressing gratitude for the provision of the Experimento materials.

Implementation of recommendations from Study 2

The proposals for improving the training course for teachers were comprehensively accepted and implemented. The training has been converted to a blended learning format that focuses on teaching methodical and didactic expertise. By moving essential content to online, self-directed phases, the key emphasis in the in-person sessions can be shifted to focus more heavily to the application of knowledge with regard to methodical and didactic expertise. This means that teachers need to independently work through the lesson units that are presented and implemented in the second in-person phase. While the focus in the online component of the training is on the self-directed acquisition of knowledge, in both methodical and didactic terms, knowledge transfer takes place in the second in-person phase. In addition, authentic video clips from classes in the digital learning phase demonstrate methodical and didactic expertise using an experiment.

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Study 3: Use of training materials/experiments and satisfaction of teachers

Objective:

The main goal of the training is to utilize the knowledge acquired in teaching and to conduct experiments with the students.

Questions:

1. **Use of the materials:** What materials are used and at what year levels? How often are the materials used and which experiments are conducted more/less frequently?
2. **Satisfaction of the teachers with the offering:** How satisfied are the teachers in everyday usage? Would they use the material again? Is the material easily accessible at school?
3. **Didactic use of the material:** Who conducts the experiment? What activities are carried out independently by the children?

Method:

Tool: Log books with 20 questionnaires to complete by the teachers, in reference to running the experiments in class
Sample:

- Germany 71 log books with 322 completed questionnaires
- Chile: 23 log books with 189 completed questionnaires

Results:

Question 1: Use of the materials/experiments

In Germany, each log book includes approx. 4 documented experiments that were mainly conducted in Years 3 and 4. The log books from Chile contain an average of 8 documented experiments. Around three quarters of the participating teachers in Germany and Chile use the instructions for teachers. Around two thirds of students in Germany and about a third in Chile use the instructions for students that can be utilized as worksheets. In this process, two thirds of teachers in Germany adapt their worksheet to their classes.

In Germany, energy was the topic that was by far most frequently opted for, with its 10 experiments. Here, the first three experiments were the most popular: simple electric circuit, conductors and insolators, and complex electric circuits. A quarter of the experiments were from the environment category, with the most frequent experiments being water cycle, water purification, and recycling. In Chile, half of the experiments that could be attributed to a particular topic were related to the environment, with the “water purification” experiment topping the list. By contrast, the experiments from the energy topic were used the least. In both countries, there were also experiments that were used only once or even not at all, which means they should be reconsidered from a resource point of view.

Revision: To ensure sustainability is taken into account, the material kits for schools will no longer be distributed on a universal basis. Rather, the contents can be ordered as required.

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Question 2: Satisfaction with the offering

Teachers in Germany who completed an experiment in the log book are very satisfied with the Experimento offering. The information about most experiments was assessed as being easy to understand and all materials necessary for the experiments were available. These generally could be stored for some time, while it was easy to procure them where necessary. Teachers in Chile are also very satisfied overall with the offering.
Teachers in Germany and Chile would be happy to use most experiments again. The materials are stored both in Germany and in Chile in an easily accessible special storage room.

Question 3: Didactic use of the material

The Experimento education program has the aim of giving children the opportunity – following the principle of inquiry-based learning – to discover and understand scientific and technological interrelationships themselves. To do this, children need to have the liberty to think and act themselves. As intended by Siemens Stiftung, teachers in Germany report that the experiments are in most cases conducted by the students themselves; in Germany most often in group or partner work.

The teachers both in Germany and Chile say that they give children scope to put forward their own hypotheses within the cognitive process. In half of the documented experiments, children in both countries were allowed to freely conduct their own research. In Germany, the children were allowed to independently interpret their results in half of the experiments. In a third of the documented experiments, the teachers gave children the opportunity to define the problem themselves and to plan the experiment independently. Independent planning of experiments and independent interpretation of the results are less common in Chile. Two core elements of scientific thinking, however, are put in the responsibility of the children less often: defining the problem and planning the experiment. The results indicated that these aspects are challenging for the children and teachers and require a certain level of scientific understanding. At the outset, i.e. for untrained pupils and for teachers with little experience with the scientific process, precise instructions with a clear structure of the cognitive process are helpful. The aim of the training could also be to show teachers how, on a step-by-step basis, they can put the cognitive process into the hands of students, what requirements they require for this and how they can integrate these into their classes. In line with this, the instructions both for teachers and students could also be revised.

Revision: A more in-depth scientific approach is taken in the blended learning training. This is structured in levels. The teachers first become familiar with the relevant content, before understanding it in a practical context. Finally, they need to independently apply this understanding. In particular, knowledge transfer only succeeds if the scientific understanding that is acquired in the training is in place.

The recommendation to design the cognitive process for the students more freely is given attention on the second in-person day of the blended learning training. This section shows different ways of achieving this in classes. Through the new addition of problem stories, which are presented at the beginning of an experiment, pupils are now able to put a greater independent focus on the resulting research questions and to look into the related assumptions.

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Implementation of the recommendations: from study 3

Under the recommendations, the research cycle was extended to include the “Identify problem or phenomenon” process step. The background story now included in each experiment aims to give students the ability to identify the problem behind it themselves. In the revised training, more attention is also given to applying what has been learned, thereby giving teachers greater certainty in experimentation. In this context, didactic opportunities can also be explored to allow pupils to develop their cognitive process independently. In addition, a needs-based ordering option for experimentation materials was introduced to conserve resources in the future.

Study 4: Implementation of Experimento | 8+ in teaching

Objective:

This study aimed to analyze specific implementations of the experiments in teaching and to make recommendations based on them.

Question:

1. What elements of the training or materials from Experimento | 8+ are used in the experiments?
2. How can the materials be developed in order to use the experiments as an effective learning situation in teaching?

Method:

Video analysis of five one-hour teaching situations with experiments from the Year 3 and 4 levels that are recorded, transcribed, and evaluated using analysis software.

Results:

Question 1: Elements and materials from Experimento

In each of the five videoed lessons, the elementary school teachers use an experiment from the handbook folder, the corresponding instructions for pupils and materials from Experimento | 8+, supplemented by their own materials. Four videos focus on water purification, while one video is on energy (conductors and insolators).
As suggested in the training and handouts, all children are allowed to conduct the experiment themselves in a group.

The research cycle in the instructions for pupiles lends a clear structure to the lessons. The problem-based approach, i.e. the use of interesting, motivating problems at the outset that are addressed repeatedly during the lesson and which encourage children to think – including using appropriate questions – can often be seen in the videos. The materials analysis shows that the instructions receive good scores both for their problem-based approach and the problem-based questions – meaning that they have indeed been of use to teachers – particularly for the experiments often conducted in elementary school (B2 water purification; A2 conductors and insolators).

The teacher’s request to formulate hypotheses and activate prior knowledge, which is consistently encouraged in the Experimento instructions, can be seen in all the videos. One teacher asks the

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children to develop the research question themselves, while another teacher first has the children freely research with the material and plan the steps of the experiment themselves, before she demonstrates the experiment.

When conducting the experiments, most teachers follow the instructions closely. All teachers first demonstrate the experiment themselves and then have the children perform it themselves, as described in the worksheet. After the experiment, the children interpret the findings by themselves in all of the video lessons and find answers to the research question.

Question 2: Recommendations for the development of the material

Recommendation 1: Support for independent experimentation

The advantage of close guidance is at the same time a disadvantage in terms of getting students to experiment by themselves. Only when confronted with the question "How can we find this out?", will the children acquire methodical knowledge about how scientific questions or problems can be resolved by experiments, what things to watch out for (e.g. the various types of variables), what mistakes can be made and what kind of experiment is suitable or unsuitable for verifying a problem. Particularly in elementary schools, this kind of process could be supported and gradually developed by teachers until children are able to plan simple experiments themselves and answer their questions independently. In the training, but also in the handouts, didactic expertise should be offered for how pupils can be guided on a step-by-step basis through independent, free experimentation. In this regard, studies report that students and teachers alike initially require close guidance, before subsequently being able to experiment more freely.

Revision: The blended learning training has been designed to take account of this approach. While close guidance tends to be used at the beginning, in the rest of the training there is the option to design the experimentation process more freely, particularly on the second in-person day of the training. During the training itself as well, greater attention is also paid to imparting and using methodical and didactic expertise.

Recommendation 2: Support for the cognitive method of ordering.

The targeted and explicit use of scientific cognitive methods, in this case assessed using the example of ordering (sorting, categorizing), is relatively rarely seen in the five videos. We suspect that teachers underestimate the great significance of the scientific methods. These are not just about the acquisition of knowledge, but also about building up approaches to thinking and working that are less context-driven than subject content and which also hold significance beyond the sciences, as the example of ordering particularly shows. Didactic enhancements to the training may be useful in this respect.

Revision: This didactic enhancement now forms part of the blended learning training. This means the individual phases in the blended learning concept closely build upon each other, in order to move from the knowledge classification of "knowing" to "being able". Particularly the willingness to experiment with various methodical and didactic options, in the context of the research cycle, is the focus at the end of the training.

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Recommendation 3: Expanding knowledge about children's thought processes

In the videos, situations can be seen in which the teacher picks up on misconceptions or false beliefs from children and encourages the children to find explanations or to discuss things with other children. In order for the teacher to be able to talk to the children about their prior knowledge, initiate discussions, pick up on misconceptions and use them as learning opportunities, the teacher needs knowledge about the significance of language as a cognitive activity and tools to motivate even reluctant or uncertain children to make these kinds of statements. To ensure the teacher can handle these statements in a subject-appropriate way that supports learning, however, he or she needs knowledge about the way in which children think, how they experience the world and scientific phenomena, what concepts and ideas are to be expected and observed at various stages and how these can be questioned, discussed, and developed further. Subject matter didactics can provide this kind of knowledge.

Revision: This knowledge is now being integrated into the blended learning training and is being focused on more heavily, particularly on the second in-person day.

Implementation of recommendations from Study 4

The suggestions for improvement from the evaluation were taken up in full in the redesign of the training. The focus in the new format is on imparting methodical and didactic knowledge, along with subject-specific material. The individual phases in the blended learning concept closely build upon each other, in order to move from the knowledge classification of "knowing" to "being able". Particularly the willingness to experiment with various didactic and methodical options, in the context of the research cycle, is the focus at the end of the training.

Study 5: Impact of Experimento | 8+ on skills and motivation of students

Objective:

In this study, the impact of Experimento on skills and motivation of students who use it is investigated.

Questions:

1. In what way do the skills of students who use Experimento differ from those who do not?
2. In what way do the skills of students who use Experimento differ from those who do not?

Method:

Comparative study of 295 students from 26 classes from the Year 3 and 4 levels, of whom 110 children were taught by teachers who had been through Experimento training.

Results:

Question 1: Skills

Proving the impact of individual educational measures on the skills of students is always a tricky business. Many factors can play a role in this and it is difficult to control for them in educational studies. In the Experimento education program, it is also a long road from the training of teachers

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and the provision of the materials to the desired changes in teaching and the learning outcomes for students. Consequently, the results need to be interpreted with caution.

The analyses show that the children in the Experimento classes, on average across the entire group (i.e. all boys and girls in Year 3 and 4) tend to do better than children in the control classes.

The impact of Experimento, however, differs across the year levels. Statistically detectable, i.e. significant, is the advantage of boys in the Experimento group vs. the boys in the control group from the cohort in the Year 3 level. Girls do not show any difference, neither in comparison with the control group, nor in comparison with the boys from the same cohort.

Within the Experimento classes from Year 4, the girls achieve significantly better results than the boys. In the Year 4 cohort, the results from the Experimento group do not show any difference from those in the control group, neither overall, nor when separated by gender.

Question 2: Attitudes

The most significant result relates to motivational attitudes: Students in the Experimento group have a significantly higher self-concept and engage with science content significantly more frequently in their free time than students in the control group. They tend to assess their interest in science as being higher than those from students in the control group. The differences relating to girls are significant: Girls benefit particularly from the use of the Experimento program when it comes to their interest. These are good motivational preconditions for the creation of sustainable and long-term scientific competencies.

The children from the Experimento group tend to assess their interest in science at a higher level than the children in the control group. The difference is larger in the cohort from the Year 4 level than in the Year 3 one. The girls in the Experimento group rate their interest at a level significantly higher than that of the boys, and also significantly higher than the girls in the control group. In the control group, there is no difference between girls and boys.

The children from the Experimento classes rate their science self-concept at a significantly higher level than the children in the control group, both across the entire group and in the two year level cohorts. Boys have a significantly higher self-concept than girls, which becomes particularly evident in the Year 4 cohort.

Students whose teachers use Experimento engage with science materials significantly more often in their free time compared with students in the control group.

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Summary of the revision and redesign of Experimento | 8+

Revision of the handouts for teachers and instructions for both teachers and students, training, ordering option

The handouts for teachers and the instructions for both teachers and students were revised based on the evaluation results and the coronavirus conditions.

- The **handouts for teachers** were completely revised. They now no longer function as supplementary material for the training, but have been included as a key preparatory component in the training concept. This means that teachers receive this document in digital form after registering for the training, to allow them to prepare for the first in-person phase. In addition to general information about Experimento | 8+, focuses are the three topic areas of energy, environment, and health, and particularly the research cycle as a way to operationalize inquiry-based learning. The research cycle is portrayed in significant detail, in order to convey methodical and didactic expertise, as well as content-based knowledge. This knowledge is revisited again and again over the remaining period of the training. It has been a priority to improve the rigor, conciseness, and quality of the content. In addition, a user-oriented aide for teachers to allow them to conduct experiments in classes was to be provided.

- The recommendation to include **suitable everyday examples** in the materials was implemented in all sets of instructions for both teachers and students. For this purpose, a new icon in the form of a jigsaw puzzle piece was incorporated at the beginning of the research cycle. This stands for the “Identify problem or phenomenon” activity. It contains an everyday example for each experiment that closely and consistently guides the user to a problem, in doing so shaping the science-related cognitive process from phenomenon to questions and hypotheses in a way that is rigorous and coherent. Where necessary, the questions and hypotheses used were changed to increase the rigor. In general, greater weight has been given to the problem-based approach to the experiment and to linking the individual steps with each other in terms of content.

- In addition, **the instructions for teachers** were expanded to include the “Reference to background story” aspect under the “Evaluate and reflect” research step. The idea behind this reference is to ensure the science-related question or problem posed at the outset is examined in a way that is critical and takes an assessment approach. In this case, there is the option for teachers to discuss with students about the extent to which their experiment contributes to answering the problem posed at the outset. Here too, there is the option of a further critical examination in terms of content.

- The assessment and critical examination of science-related content is addressed as its own process activity in the research cycle, in connection with **value formation** in order to give this topic appropriate treatment, a dedicated digital module has been launched which has been enhanced with a specific sample lesson. In this module, ways of reflecting with the students about the topic treated in the experiment are presented. Teachers can be encouraged to productively use these for their own teaching.
- Opportunities for free variation or for using variable control strategies that were recommended in the evaluation are covered as part of the **“Further research“** activity. In this activity, students can carry out additional experiments on the particular topic with relatively little guidance. This option, however, is normally taken up only by the more competent students.

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Redesign of the training for teachers

The training for teachers was redesigned, particularly for the purpose of integrating a digital component. A key demand was for the length of the training to be two days. To allow this and to facilitate a high-quality training session, the training was designed as blended learning. This training consists of four phases:

1. Digital preparation phase,
2. In-person phase,
3. Digital phase and
4. Second in-person phase.

The aim of this concept is to allow more in-depth engagement with the taught content and to allow the focus to be placed on methodical and didactic expertise. Key suggestions from the evaluation include both increasing the level of methodological expertise for teachers and improving didactic knowledge. In order to achieve this, the following elements were implemented in the redesign of the training for teachers:

- **Close didactic integration of the four phases of the blended learning concept to build and enhance methodological and didactic knowledge.**
  The four phases of the blended learning concept are closely linked with each other in terms of content.
  For example, the digital preparation phase serves to give teachers an initial insight into the Experimento education program and to present all important documents and content, including the research cycle. For this purpose, teachers receive a handout for educators which presents the key content and refers to examples in the digital learning module. In the first in-person phase, there is a more in-depth presentation of the training content. In this component, the research cycle and its demonstration by way of an experiment are the focus, with the aim of supporting the acquisition of methodological knowledge. This phase ends with a task for teachers of creating a lesson plan for an experiment by the time of the second in-person phase. The aim of the digital phase is to create the foundations for teachers to develop their own teaching for the particular experiment. In this component, methodological and didactic knowledge is explained using the research cycle. The second in-person phase aims to apply the acquired expertise in specific teaching scenarios. The implementation of specific lesson plans and co-operative discussion about them are the focus of this stage.
  Knowledge acquisition therefore builds over the four phases. While the first two phases are directed at the “Identify knowledge” aspect, application and transfer to current teaching scenarios are the focus of the third and fourth phases. When this is shown by another teacher in a video in the digital phase, self-directed implementation by the teachers themselves comes in the fourth phase (“Apply knowledge”). The reason for this: the aim is not just for teachers to become familiar with methodical and didactic knowledge, it is also important for them to have the ability to use and apply this in a specific teaching context.
- **Digital presentation of the material with the help of teaching videos to explain the content of the research cycle and to demonstrate it.** Although teachers are familiar with the research cycle, they also keep very closely to the instructions included in the cycle. In order to provide teachers with greater flexibility in dealing with the materials and experiments, they require methodical and didactic expertise. A particular focus is placed on this in the digital learning module about the research cycle. For example, in the “Formulate a research question” and “Collect ideas and hypotheses” steps, theoretical explanations and complex tasks relating to methodical l and didactic knowledge have been integrated. In ad-

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dition, the videos from the sample lesson have also been able to be used to show the difficulty of moving from a problem to an adequate research question. The reason for this: The chosen research question in the video lesson did not exactly suit the following experiment. This circumstance was addressed in the module, prompting the teachers to reflect about the individual research steps.
At the same time, the lesson demonstration using video clips can also reduce reluctance from teachers to allow students to experiment by themselves, particularly in a “free” format. In the evaluation, it was reported that teachers put the focus on the students conducting the experiments correctly. The sample lesson integrated into the digital learning unit shows using an evaluation of an experiment that a group of students had problems with conducting it “correctly”. In this video clip, it is demonstrated that incorrectly conducted experiments can still increase students’ learning.

- **Application of learning in a group format** The fourth phase is focused on drafting lesson plans to solidify and apply what has been learned in a self-directed manner in class. In this phase, the teachers develop a specific didactic concept for conducting an experiment that follows the stages in the research cycle. By taking this approach, the methodical and didactic knowledge can be expanded and covered in more depth with the help of discussions. Suggestions for allowing students to experiment in a free and more self-directed manner can also be made at this point. If teachers feel more certain in their didactic planning and in the implementation of experiments in their lessons, options for how teachers can put the cognitive process in the hands of the students can also be explored. This means that teachers can give students more and more responsibility for finding the problem question themselves, planning the experiment, and experimenting independently.
- **Emphasis of the value aspect:** A dedicated learning module on value formation has also been developed for the digital phase. By way of a sample lesson on “How can we protect our water”, which builds on the previous lesson on an experiment for water purification, students develop practical ways of protecting water that they can themselves implement in their everyday lives. In this process, the teacher draws on a wide range of didactic methods.
- **Drafting of the handout for multipliers:** As part of the revised training, the **handout for multipliers** was also completely revised and updated. The focus of this is explaining the training’s blended learning concept. The individual steps are set out based on the underlying idea, objectives, procedure, and potential didactic implementation.

Needs-oriented ordering option for experimentation materials

The results from the use of the experimentation materials show that not all experiments are conducted on the same scale. From a resources point of view, the previous situation meant materials – in class sets – were provided in volumes that were not required. The distribution of experiment kits will therefore be dispensed with. Instead, a needs-based ordering option is being created. This means that teachers can order the materials specifically for the experiments that they choose.

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