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INVIGORATING STEM

Extracurricular Science Labs for STEM Talent Support

Dieter Hausamann

In the past decade, a growing lack of engineers, natural scientists, information technology experts, and mathematicians has been noted, especially in Europe. Corresponding to the need to attract young people to science and technology, numerous extracurricular science labs ("out-of-school labs") have been established, especially in Germany. One of these initiatives is the DLR_School_Lab Oberpfaffenhofen, operated by Germany's national research center for aeronautics and space, DLR, and a typical example of such an out-of-school lab. It offers hands-on experiments for secondary-school classes, advanced teacher training, and, as a special feature, enrichment courses for gifted students. In this article the concept behind the DLR_School_Lab is described, as well as the suitability of this lab to offer enrichment projects for talented school students. Other aspects discussed are its teacher education concept and the effectiveness of the concept of extracurricular science labs.

Keywords: acceleration, assessment, enrichment, science and technology, secondary school, STEM, talent development, teacher training, teachers of the gifted

In Germany there presently is a lack of more than 60,000 engineers and scientists, and this gap is expected to increase to 425,000 by 2020 (Stahl, 2009). Similar apprehensions exist with respect to the European and U.S. science and engineering workforce, as discussed by Osborne and Dillon (2008) and EurActiv (2008), as well as by the Committee on Prospering in the Global Economy of the 21st Century (2007) and Butz et al. (2004).

Different names are used to describe the workforce affected by this phenomenon: in the United States the term is STEM (science, technology, engineering, and mathematics, which will be used in the remainder of this article); in Germany, MINT (mathematics, informatics, natural sciences, and technology); Tengelin (2009) called it MST (mathematics, science, and technology); and another frequently used name is S&T (science and technology).

The need for STEM specialists is determined by two factors—demand and supply:

1. The demand is defined by the labor market. Stahl (2009, Figure 4) estimated an overall demand of 1,300,000 German STEM specialists by 2020, driven by the retirement of 700,000 retired and 600,000 newly created job opportunities in the area of STEM. The United States Department of Labor, Bureau of Labor Statistics (2010) expects that in 2018 in the United States, 1,750,000 engineers will be employed, compared to 1,600,000 in 2008.
2. The supply is governed by the development of the STEM workforce and the motivation of young people to take up a STEM profession. In his analysis of the factors regulating the supply, Tengelin (2009, Figures 21 and 131) showed that the situation in Europe is dominated by an extremely negative demographic development, whereas this demographic factor is much more positive for the United States. A distinct and growing unpopularity of STEM professions on the part of young people is, however, common to all industrial countries. Analyzing data from 1975 to 1999, Butz et al. (2003, Figure 3) showed that "a young adult's probability of getting an S&E degree has risen much less in the United States than abroad." "Why Don't

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> Young People Want to Become Engineers?" is the title of a recent publication (Becker, 2010, p. 349) comprising an in-depth analysis of this phenomenon. As a major conclusion the author stated that it is necessary to dedicate "resources to make it possible for students to come into contact with practical work" (p. 364).

The impact of the STEM gap on economic revenue has been estimated by the Association of German Engineers and the German Institute for Economic Research (Koppel, 2008): in 2007, due to a STEM gap of about 80,000, the German economy lost more than 7 billion euro (approximately $10 billion). Tengelin (2009) set up a complete mathematical model to estimate the financial loss for one of the big Swedish companies, the Volvo Group, caused by not investing money to reduce its STEM workforce deficit: for the period 2010–2025 an overall loss of 1.8 billion Swedish crowns (about $250 million) could be expected. A more general study by McKinsey (2009) investigated the economic impact of the achievement gap in America's schools:

> This report finds that the underutilization of human potential in the United States is extremely costly. . . . For the economy as a whole, our results show that: If the United States had in recent years closed the gap between its educational achievement levels and those of better-performing nations such as Finland and Korea, GDP in 2008 could have been $1.3 trillion to $2.3 trillion higher. This represents 9 to 16 percent of GDP. (p. 5)

Attracting talented young people to science and technology is a societal task deserving the utmost priority in Europe, as has been stated by the workshop "Meeting the Needs of Gifted Children and Adolescents: Towards a European Roadmap" organized strategically by the European Cooperation in Science and Technology (COST, 2007). The major result of this workshop was the resolution, "Action Plan for the Gifted and Talented—An Essential Part of the Lisbon Strategy." This resolution is addressed to the European Commission, one of its main requests being to "involve scientists, research facilities and industry in the development of education for our gifted and talented" (p. 1). The situation in the United States was discussed by Hira (2007), who especially addressed the so-called talent pool as "the lifeblood of the STEM workforce system" (p. 6). Gates (2007) expressed his apprehension that "demand for specialized technical skills has long exceeded the supply of native-born workers with advanced degrees, and scientists and engineers from other countries fill this gap. This issue has reached a crisis point" (p. 1).

In a recent article, Wörner (2011) summarized the effect of the STEM gap from the point of view of a chief executive officer of a large-scale European research establishment. He reported on the measures taken by the German Aerospace Center DLR to overcome this problem by attracting STEM talents.

Heller (2007) discussed the subject of scientific and technical intelligence. He came to the conclusion that it "seems that the key to success in the nurturing of the highly gifted and talented youth in mathematics, the natural sciences and technology lies primarily in the motivational and self-concept prerequisites" (p. 227).

The lack of science and engineering students indicates that the existing educational system cannot fulfill this task appropriately; obviously, regular curricula do not provide sufficient information and motivation for students to become involved in science and technology. Because of this lack of information at school, many secondary-school students—even at the end of their schooling—seem to be unable to make any decision about their future study or professional goals.

The situation is even more difficult for gifted students because their talents often allow for a greater number of choices. Because gifted students are often underchallenged by regular school lessons, their great potential is not used or appropriately stimulated. Gifted youth are not per se motivated to make use of their talent; they rather lose interest and motivation by being educated at a lower intellectual level than is suitable for them.

It is extremely helpful for this group to come into close contact with the demanding professional environment of engineers and scientists. This gives them a chance to incorporate the role of a researcher in the framework of an actual science project and to deal with institutions directly involved in research and development.

In order to attract young people to STEM and interest them in the respective university disciplines, many extracurricular science labs have been established over the last decade by research centers and universities all over Europe. According to the Leibniz-Institute for Science Education (IPN) at the University of Kiel, Germany, close to 300 of them are in Germany (LernortLabor [LeLa], n.d.).

In a typical out-of-school lab students are enabled to perform high-tech experiments autonomously and on their own responsibility. The specifics of a typical out-of-school lab, as well as the role of experiments and the importance of authentic learning environments as critical factors for up-to-date physics education, have been discussed by Euler (2004). The effectiveness of out-of-school labs has recently been demonstrated by Pawek (2009). A comparable study with respect to education in biochemistry and molecular biology was conducted by Scharfenberg, Bogner, and Klautke (2007). All of these studies show the important role of authentic experimentation as the key success factor of an out-of-school lab. The pedagogical concept is based on a methodology called *inquiry-based science education* (IBSE), which has been recommended by the European Commission (2007).

In order to achieve a sustainable impact, the typical one-day visit to an out-of-school lab must be complemented by the mathematics and science teachers in the classroom. They have to interconnect high-tech experiments and research on the one hand with the standard curriculum and school lessons on the other. It requires relevant skill enhancement and advanced teacher training to establish a link between extracurricular activities at the out-of-school lab and the standard school curriculum.

In this article, the DLR_School_Lab Oberpfaffenhofen is presented as a typical extracurricular science lab operating in the context of DLR's research site in Oberpfaffenhofen and offering programs for secondary-school classes. Second, the out-of-school lab's methods of talent development are described, including several practical examples of enrichment projects. Third, feedback from students and teachers is presented, as well as the results of two recent evaluation studies. Finally, the concept and practical experience of teacher training—especially with respect to gifted education—is demonstrated.

The DLR_School_Lab Oberpfaffenhofen: An Extracurricular Science Lab—The German Aerospace Center DLR

DLR (n.d.) is Germany's national research center for aeronautics and space. Its extensive research and development work in aeronautics, space, energy, transport, and security is integrated into national and international cooperative ventures. As Germany's space agency, DLR has been given responsibility for the forward planning and the implementation of the German space program by the German federal government as well as for the international representation of German interests.

Approximately 7,000 people work for DLR in 35 institutes and facilities at 16 locations in Germany. In Oberpfaffenhofen near Munich (Bavaria), DLR employs about 1,600 people, making it one of Germany's largest research locations. The main activities of the 5 institutes in Oberpfaffenhofen are devoted to space missions, climate research, development of Earth observation systems and technologies, the European space-based navigation system Galileo, and research in robotics. These activities are complemented by two space operation centers, research flight operations, and the German Remote Sensing Data Center.

The DLR_School_Lab Oberpfaffenhofen

The German Aerospace Center started its DLR_School_Lab program in 2000 and decided to finance it by internal funding (approximately $4 million per year). Currently (2011), DLR operates nine extracurricular science labs, one of which is the DLR_School_Lab Oberpfaffenhofen (n.d.). This out-of-school lab offers secondary-school students the opportunity to conduct high-tech experiments based on the core research areas and technology fields of the DLR institutes in Oberpfaffenhofen as well as the authentic research atmosphere of a large-scale research center. The students experience aerospace research and become acquainted with a number of fields as well as with the working methods of high-technology research. The DLR_School_Lab presently offers 12 experiments in which students can become acquainted with infrared, laser, and radar technology; environmental remote sensing; meteorology; satellite Earth observation data; satellite navigation; robotics; telepresence; virtual mechanics; research flight operation; and mobile rocket research.

In a typical one-day visit to the DLR_School_Lab, each student can perform two of these experiments corresponding to his or her personal scientific interest. Each experiment comprises 2 hours of intense activities and experimentation in the respective technological field, and by the end of the day the student has gained insight into two research areas and their respective working methodologies.

One key success factor of this extracurricular science lab is the chance to carry out autonomous and responsible work with advanced and costly high-tech equipment that is unavailable at school. For example, the students are allowed to operate a reflection spectrometer, an infrared camera, or mobile laser and radar systems or work with sophisticated simulation programs.

The students are supervised and supported by university students as well as DLR scientists. However, in principle they are stimulated to work independently and regulate themselves in order to gain practical experience in interesting fields of applied research, extend their personal horizons, and learn basic principles, physical, technical, and geoscientific interrelationships, as well as applications for the science and technology represented in their chosen experiments. They work in small groups of four to six students, which both generates a stimulating working atmosphere and binds them together as a team. The teachers escorting their classes to the DLR_School_Lab are requested not to interfere with the experimenting group and to restrict themselves to remotely observing the experiments.

The standard visit to the DLR_School_Lab Oberpfaffenhofen is, in general, complemented by visits to the German Space Operation Center (GSOC) and to the recently opened Galileo Control Center, which provide insights into the control of satellites, the research activities on the international space station (ISS), and the operation of Europe's future satellite navigation system. Since it opened in 2003, approximately 15,000 students have conducted experiments in the context of DLR_School_Lab Oberpfaffenhofen.

OFFERS TO GIFTED STUDENTS

Acceleration and enrichment are proven measures to foster the development of gifted students. For this purpose, Renzulli and Reis (2002) developed the schoolwide enrichment model (SEM), which is especially appropriate for overcoming the limits of school curricula and opening the door to the fascination of science and research. This approach, however, requires the cooperation of schools with experienced research partners who are able to communicate enthusiasm for their respective disciplines.

One of the key objectives of the DLR_School_Lab Oberpfaffenhofen is to promote especially gifted young people (Hausamann, 2005). Because the lab's experiments are derived from current research activities at the DLR institutes, they are particularly adaptable to the potential of highly talented and motivated students because there are no inherent limits to their scientific depth and complexity. The same holds for the supervising scientists and students, whose personal expertise exceeds by far what is available even at the highest school levels. In past years the out-of-school lab has developed, conducted, and successfully completed about 30 special projects and events for highly talented students.

It should be emphasized that the DLR_School_Lab is not involved in the process of identifying the giftedness and talents of the visiting groups. Most of the gifted student groups come from schools with special advanced classes or from official enrichment programs for gifted students; that is, the participants have been previously tested, identified, and selected.

In principle, there are two possibilities for such enrichment projects: (a) regular visits to the DLR_School_Lab and (b) Type III enrichment projects.

Regular Visits to the DLR_School_Lab

The science content of out-of-school lab experiments can be used to overcome the constraints of the regular curriculum; that is, to go beyond the standard content of school lessons. It can be adapted to the special conditions and requests of talented students in the following ways"

- *By early acquaintance.* Gifted students might be able to perform complex experiments at a younger age than regular students. A typical example is the robotics experiment ASURO (Wikipedia, n.d.), which involves assembling and programming a complete robot rover and is typically suitable for regular high-school students aged 16 and above. Numerous highly gifted students have assembled the robot successfully at a much lower age, down to age 12 (cf. Hausamann, 2005).
- *By extension.* When performing an experiment, talented students have the chance to penetrate to complex levels of the underlying physical theories. They can develop and perform more sophisticated experimental techniques or they can design more complex programs and analytic methods than regular students can. These options have been utilized extensively by gifted students attending the out-of-school lab.

Early acquaintance and extension are measures corresponding to the standard pedagogical and administrative methodologies of gifted education, acceleration and enrichment, respectively. The DLR_School_Lab has gained much of its relevant experience from the special classes for gifted students at the Maria-Theresia-Gymnasium in Munich (n.d.). About 20 of these classes have visited the out-of-school lab in the past 7 years.

Type III Enrichment Projects

Renzulli and Reis's (2002) SEM provides a practical way for school programs to identify and foster the academic growth of school students with exceptional abilities and to help young people develop their talents. Renzulli and Reis introduced three types of enrichment activities of increasing complexity and difficulty. Type III enrichment is the most advanced stage of this individual promotion model. This type of enrichment activity provides opportunities for students to work in a self-directed manner on a subject, develop convincing products, and assume the role of a researcher.

The scientific and technological research fields of the DLR institutes are very suitable for Type III enrichment projects. Subjects such as satellite navigation or satellite remote sensing are, on the one hand, characterized by their high timeliness and application relevance. On the other hand, the scientific issues are mostly complex and are not covered in standard school curricula.

A typical Type III enrichment project initiated by the DLR_School_Lab is characterized by the following:

- A general subject derived from the DLR research fields.
- A more specific project outline defined by the supervising teachers and the DLR_School_Lab.
- A selection process in which the class or group makes a decision in favor of this project (against alternative choices).
- The student's responsibility for the specific tasks and objectives, as well as for the organization and management of the project.
- Teachers and scientists in the role of consultants, supporting the students on demand.
- An extension over a period of several months.
- A 2- or 3-day visit to the DLR_School_Lab Oberpfaffenhofen as an essential project activity.
- The responsibility of the students for the public presentation of the project results.

Between 2004 and 2010, seven Type III enrichment projects were carried out:

1. The Space Robotics Project of the Hector Seminar in May 2004
2. The GPS Einstein Project of the Christophorusschule Königswinter in November 2005

3. The Geophysics Project of the Hector Seminar in May 2006
4. The Satellite Navigation Project of the Internatsschule Schloss Hansenberg in May 2007
5. The GALILEO Project of the Hector Seminar in May 2008
6. The Geophysics Project of the Internatsschule Schloss Hansenberg in February 2009
7. The Remotely Controlled Roboting Project of the Hector Seminar in May 2010

The following two examples are typical for all of these enrichment projects.

The GPS Einstein Project

Satellite navigation is one of the rare technical applications that is strongly influenced by Einstein's theory of relativity. The goal of the GPS Einstein project (Hausamann & Schmitz, 2007) was to quantitatively investigate this influence on the precision of localization. The project involved a 12th-grade physics course for gifted students at the Christophorusschule Königswinter and lasted approximately half a year.

In the first phase, the students familiarized themselves with Einstein's theory of relativity and satellite-based navigation. The second phase of the project was a 3-day excursion to the DLR_School_Lab Oberpfaffenhofen. The program of this visit was tailored to the requirements and abilities of a group of exceptionally gifted students. One important pedagogical feature was continuous alternation between self-regulated experimental activities and university-level science lectures. In the third and final phase of the project the students completed the project. They derived the frequency shift of the Global Positioning System (GPS) satellite clocks and the consequences thereof. The students presented their final results at a National Students' Congress in Munich in December 2005, which was devoted to Albert Einstein's life and research.

The Geophysics Project: Remote Sensing From Satellites

The scientific focus of the enrichment project "Geophysics—Remote Sensing From Satellites" was on the properties of the solar radiation spectrum and its influence on the geosystem. The goal of this Hector Seminar project was to investigate changes in the participants' home environments by analyzing and comparing remote sensing data from satellites collected over a period of time (Hausamann, Wilke, Taulien, Grixa, & Locherer, 2009).

In a one-day workshop in April 2006, the students were introduced to the requisite scientific background, methodologies, and technologies. In May 2006 the Hector Seminar students spent 3 days at the DLR_School_Lab Oberpfaffenhofen focusing on environmental measurement technologies and accessing, processing, and analyzing satellite data. The third project activity was a measurement campaign in Heidelberg. Based on information and results from the measurement campaign, the students performed the final task of the project. They classified satellite images and analyzed changes in their home environment between 1989 and 1999 and, finally, produced reports on the results. In September 2006 the students presented these results at the Hector Seminar Project Workshop in Mannheim. The exceptional work of this group received the DLR_School_Lab Prize 2008, which is awarded annually by the Society of Friends of DLR, based on nomination by the DLR Executive Board.

ASSESSMENT AND EVALUATION OF EXTRACURRICULAR SCIENCE LABS

Because extracurricular science labs require considerable financial and human resources, it is essential to ascertain their effectiveness in general, and in this case that of the DLR_School_Lab Oberpfaffenhofen in particular. Because out-of-school labs have only existed for 1 decade (the first DLR_School_Lab started operations in 2000 in Göttingen), there have been no full evaluation and assessment studies of their effectiveness involving a standard methodology with control groups. However, several initial studies provide strong evidence for the effectiveness of this concept. In this section the results of different approaches and methodologies to assess effectiveness are described, namely:

- The analysis of more than 9,000 questionnaires—immediate feedback from students after visiting the out-of-school lab.
- A qualitative investigation of differences between the reactions of regular and gifted students (Stumpf, Neudecker, & Schneider, 2008).
- An analysis of the questionnaires and feedback from participants of the seven Type III enrichment projects mentioned above.
- An evaluation of four DLR_School_Labs (including the Oberpfaffenhofen lab) to assess their impact on the students' interest and any changes in their self-concept (Pawek, 2009).
- A longitudinal evaluation of the Hector Seminar, an extracurricular enrichment program (Heller, 2009; Heller, von Bistram, & Collier, 2010) involving the DLR_School_Lab as one of the external project partners.

Assessment of Regular Visits by Students

The first qualitative source of information is the students' immediate reactions after visiting the out-of-school lab. This information is gathered from anonymous questionnaires and oral statements. At the end of a visiting day, both types of feedback are requested from each participating student. The questionnaire addresses the following general items, with a choice between *yes, no, and don't know*:

1. This was the first visit to the DLR_School_Lab.
2. My expectations were satisfied.
3. The duration of the visit was too long.
4. The mentoring was good.
5. The experimental subjects were too complicated.
6. The visit to the DLR_School_Lab has increased my interest in natural sciences.
7. I'll talk about this visit to my parents, friends, and relatives.
8. I'd like to come again to conduct other experiments.
9. It was fun to do experiments.
10. The relation of the subjects to everyday life was obvious.
11. I plan to take up a job in science or technology.

Furthermore, the students are asked to assess the general introduction and the visit to the Space Control Center, as well as to comment on what could be done better.

Finally, they are asked to assess each individual experiment they performed, with a choice among the options ++, +, o, −, and −−:

- Was the subject of the experiment interesting for you?
- How was the introduction to the experiment?
- How did you understand the subjects?
- How was the supervision of the experiment?

The general feedback (questions 1 through 11) was evaluated for approximately 9,000 (6,400 male and 2,600 female) questionnaires collected between January 2006 and May 2011 for classes having visited the out-of-school lab for 1 day. The results are shown in Table 1 and indicate the following:

- 93% of the students visited the out-of-school lab for the first time.
- The expectations of 87% were satisfied.
- 78% agreed with the duration of the visit.
- Only 1% criticized the supervision.
- The level of the experiments was well chosen for 96%.
- 62% expressed that the visit had increased their interest in STEM.
- 80% intended to speak about the visit with parents or friends.
- 66% would like to come again.
- 96% had fun doing the experiments.
- 78% considered the experiments relevant for everyday life.
- 49% planned to take up a STEM career.

The most important feedback is the increased interest in STEM resulting from the visit to the out-of-school lab—even if this statement is subjective and certainly also a result of the positive atmosphere immediately after an inspiring day. A further study has been started recently: By means of a questionnaire sent to students at the end of secondary school we wanted to find out whether a former visit to the DLR_School_Lab influenced their study decision. Even if quantitative results are not yet available, there is much feedback from students showing that their decision to pursue a STEM field of study was enhanced by the visit.

Assessment of Gifted Students' 1-Day Visits to the Out-of-School Lab

The effect of the visits to the DLR_School_Lab Oberpfaffenhofen on gifted students was investigated in a pilot study conducted by the University of Würzburg (Stumpf et al., 2008). In this study, the feedback and questionnaires from gifted students were compared with the responses from regular classes. The study comprised data from 180 students, 79 from gifted classes and 101 from regular classes. All data were collected after 1-day visits to the out-of-school lab.

The general assessments of the visits are unambiguously positive for all students. More than half of them confirmed that their interest in natural sciences was enhanced by the visit. Almost half of the students intended to aim for a technical or science profession.

There were no significant gender differences in the feedback. This was ascertained for many details, such as personal interest, comprehension, and introduction to and supervision of the experiments.

In this study, significant differences between regular and gifted student groups were found. For example, compared to 85% of the gifted, only 66% of the regular students indicated their interest in another visit to the out-of-school lab. Interest in the individual experiments differed for the two groups; the more difficult experiments ranked higher among the gifted students. As an overall result, the feedback from the gifted participants was more positive than that from students in regular classes.

This pilot study did not investigate long-term effects; for example, the influence of a visit to the out-of-school lab on college study decisions or the long-term development of individual interests. However, the University of Würzburg group has proposed a study to investigate the long-term influence of out-of-school labs involving several labs in Bavaria and based on a control group design.

Students' Assessment of the Type III Enrichment Projects

For the seven Type III enrichment projects described above, feedback was collected from 54 participants (41 male and

TABLE 1
Evaluation of General Comments for Approximately 9,000 Questionnaires (2006–2010)—One-Day Visits by Regular Classes

Assessment by All Students	*Yes*	*% Yes*	*No*	*% No*	*Don't Know*	*Total*
(a) All Studentss						
First visit	8,471	93	599	7	1	9,071
Expectations satisfied	7,831	87	326	4	879	9,036
Duration too long	1,889	21	7,093	78	79	9,061
Supervision good	8,905	97	84	1	189	9,178
Experiments too complicated	341	4	8,666	96	37	9,044
Interest in STEM increased	5,676	62	1,941	21	1,477	9,094
Talk about this visit	7,373	80	772	8	1,040	9,185
I'd like to come again	5,970	66	1,346	15	1,754	9,070
It was fun to do experiments	8,720	96	281	3	42	9,043
Relation to everyday life	7,065	78	923	10	1,095	9,083
I plan a job in STEM	4,511	49	2,254	25	2,351	9,116
(b) Male Students						
First visit	5,931	93	462	7	0	6,393
Expectations satisfied	5,627	88	222	3	525	6,374
Duration too long	1,138	18	5,190	81	68	6,396
Supervision good	6,321	97	59	1	129	6,509
Experiments too complicated	212	3	6,149	96	16	6,377
Interest in STEM increased	4,233	66	1,242	19	945	6,420
Talk about this visit	5,042	79	595	9	778	6,415
I'd like to come again	4,390	69	871	14	1138	6,399
It was fun to do experiments	6,187	97	179	3	25	6,391
Relation to everyday life	5,083	79	634	10	701	6,418
I plan a job in STEM	3,715	58	1,156	18	1571	6,442
(c) Female Students						
First visit	2,540	95	137	5	1	2,678
Expectations satisfied	2,204	83	104	4	354	2,662
Duration too long	751	28	1,903	71	11	2,665
Supervision good	2,584	97	25	1	60	2,669
Experiments too complicated	129	5	2,517	94	21	2,667
Interest in STEM increased	1,443	54	699	26	532	2,674
Talk about this visit	2,331	84	177	6	262	2,770
I'd like to come again	1,580	59	475	18	616	2,671
It was fun to do experiments	2,533	96	102	4	17	2,652
Relation to everyday life	1,982	74	289	11	394	2,665
I plan a job in STEM	796	30	1,098	41	780	2,674

13 female) in anonymous questionnaires (see Table 2). The questionnaire described above has been used since 2006, whereas feedback from earlier groups was collected using a different type of questionnaire; the three questions that matched those in the new questionnaire were also included in the analysis (20 male, 5 female). It indicated that:

- 95% of the students visited the out-of-school lab for the first time.
- The expectations of 85% were satisfied.
- 96% agreed with the duration of the visit.
- None of the students criticized the supervision.
- The level of the experiments was well chosen for 98%.
- 65% expressed that the visit had increased their interest in STEM.
- 93% intended to speak about the visit with parents or friends.
- 81% would like to come again.
- 94% had fun doing the experiments.
- 93% considered the experiments relevant for everyday life.
- 65% planned to take up a STEM career.

In comparison with the evaluation of all of the 1-day visits, most answers indicated that participants shared the same positive feelings. However, there were pronounced differences:

- Participants in Type III projects show an increased interest in continuing their work. In comparison to the regular student group, a remarkably higher fraction (15%) of the gifted students wished to visit the out-of-school lab again, which is quite considerable, because all of these students had already spent 2 or more days in the out-of-school lab.

TABLE 2
Evaluation of General Comments (2004–2010)–Multiday STEM Enrichment Courses for Talented Student

Assessment by All Students	*Yes*	*% Yes*	*No*	*% No*	*Don't Know*	*Total*
(a) All Students						
First visit	75	95	4	5	0	79
Expectations satisfied	67	85	4	5	8	79
Duration too long	2	4	52	96	0	54
Supervision good	54	100	0	0	0	54
Experiments too complicated	0	0	53	98	1	54
Interest in STEM increased	35	65	14	26	5	54
Talk about this visit	50	93	1	2	3	54
I'd like to come again	64	81	7	9	8	79
It was fun to do experiments	51	94	3	6	0	54
Relation to everyday life	50	93	1	2	3	54
I plan a job in STEM	35	65	5	9	14	54
(b) Male Students						
First visit	57	93	4	7	0	61
Expectations satisfied	51	84	4	7	6	61
Duration too long	2	5	39	95	0	41
Supervision good	41	100	0	0	0	41
Experiments too complicated	0	0	40	98	1	41
Interest in STEM increased	28	68	10	24	3	41
Talk about this visit	37	90	1	2	3	41
I'd like to come again	51	84	5	8	5	61
It was fun to do experiments	39	95	2	5	0	41
Relation to everyday life	38	93	0	0	3	41
I plan a job in STEM	29	71	5	12	7	41
(c) Female Students						
First visit	18	100	0	0	0	18
Expectations satisfied	16	89	0	0	2	18
Duration too long	0	0	13	100	0	13
Supervision good	13	100	0	0	0	13
Experiments too complicated	0	0	13	100	0	13
Interest in STEM increased	7	54	4	31	2	13
Talk about this visit	13	100	0	0	0	13
I'd like to come again	13	72	2	11	3	18
It was fun to do experiments	12	92	1	8	0	13
Relation to everyday life	12	92	1	8	0	13
I plan a job in STEM	6	46	0	0	7	13

- The Type III project participants showed a much stronger intention to aim at a profession in science or technology. The result was the same as above, a remarkably higher fraction (15%) of the gifted students considered a job in one of the STEM disciplines.

In summary, the feedback from the gifted and talented participants involved in the DLR_School_Lab's Type III enrichment projects was even more positive than that from students in regular classes. This also was expressed in individual oral statements made by the participants, in which they emphasized the importance of the project as well as their visit to the out-of-school lab. The following assessment is quite typical for all the projects.

On the occasion of a visit to the Christophorusschule Königswinter in May 2006 (half a year after termination of the GPS Einstein project) there was an opportunity to talk to the students who had participated in this project. They reported that it had left a deep and very positive impression. According to the students' conclusions, their participation had strongly influenced their personal decisions to study physics, chemistry, information technology, and mechanical engineering.

The Effectiveness of Extracurricular Science Labs

The feedback collected at the DLR_School_Lab Oberpfaffenhofen is, to a considerable extent, only qualitative. A quantitative assessment of the effectiveness requires a scientifically and methodically comprehensive evaluation study. Such a study was performed by the Leibniz Institute for Science Education at the University of Kiel, Germany, in the framework of a PhD thesis by Pawek (2009). Four DLR_School_Labs located in Berlin, Göttingen, Köln, and

Oberpfaffenhofen were investigated. The key questions of this long-term study were as follows:

- To what extent are out-of-school labs able to promote, or even change, students' interest and self-concept in natural sciences and technology?
- Which factors contribute to this process?

The main features and findings of this study were as follows:

- The assessment is based on the person–object theory of interest (POI) of the Munich Group (Krapp, 2002). It defines interest as a special relation between a person and an object of interest. In accordance with POI, interest has three characteristic features: emotional, value-oriented, and epistemic components. With regard to the study, this means whether the visit to the out-of-school lab was fun for the students, whether they experienced the event as personally important, and whether they want to pursue further the topics presented in the laboratory.
- The data were collected using three different questionnaires in a pre/post/follow-up approach. The first assessment (T1) took place directly at the beginning of the laboratory event, the second (T2) at the end of the visit, and the third (T3) 6 to 8 weeks later in school. In addition to other aspects, the self-concept of abilities in science was evaluated in each questionnaire (T1, T2, T3). All three components of actual interest were assessed immediately after the visit and 6 to 8 weeks later (T2, T3).
- A total of 734 students (303 female and 431 male) completed all three questionnaires. A latent class analysis of the fields in which the students were outstandingly engaged revealed three groups: the first group (A) was occupied with mathematics, sciences, and technology. The second (B) was primarily involved in social, linguistic, and artistic areas. A third group (C) showed below-average engagement in almost all areas.
- The results from the second (T2) and third (T3) questionnaires showed that a visit to an out-of-school laboratory stimulated most of the students. It was regarded as personally important by more than 50%. About half of this number would like to continue studying the topics investigated in the laboratory. In two (emotional and value-oriented) of the three components of actual interest there were no significant differences among the three student groups. Only the epistemic component of group A was significantly higher. The results of the third questionnaire yielded the same picture as those of the second one.
- A comparison of the second (T2) and third (T3) assessments showed that there were no changes in the value-oriented component across groups, whereas the emotional component decreased in groups A and B, and due to a redraft of the questionnaire the epistemic component decreased in all groups.
- The results from all three questionnaires showed that the self-concept of groups A and B increased significantly between the first and last examination after 6 to 8 weeks, whereas the changes were small within group C.

Pawek (2009) summarized:

> [T]he analysis proves that the laboratories can even have a positive influence on the only slowly changeable dispositional interests of adolescents. In sum, the learning laboratories [i.e., the out-of-school labs] successfully promote the interests of adolescents on different levels and in various ways, particularly since all effects are still verifiable even weeks after attending the laboratories. Therefore, they make an important contribution to promoting young talents and safeguarding the future of our society. These new findings partly go far beyond the results of earlier studies. (p. vi)

Recently, the study was continued by questioning students approximately 1 year after their visit to the out-of-school lab. Initial results showed that the change in the students' interest was still observable, indicating that the change in dispositional interest is a sustained effect (Pawek, 2012).

The Hector Seminar: A Scientifically Evaluated Extracurricular Enrichment Program

The Hector Seminar is a program to foster the development highly gifted secondary school students by providing enrichment activities in the areas of mathematics, information technology, natural sciences, and technology (MINT/STEM; Heller, 2009; Heller et al., 2010). Since 2001 the program has been financed and supported by the Hector Foundation. The Hector Seminar supports especially gifted secondary-school students on a long-term basis throughout their school careers. The seminar program supplements regular school activities from sixth grade to twelfth grade. The projects have an interdisciplinary character; the main objectives are to facilitate a holistic development of personality; activate and develop cognitive, methodical, personal, and social potentials; and expand the corresponding competence and capabilities. Each seminar course per cohort comprises 60 students chosen in a two-stage selection process from all 7,500 sixth-grade students attending secondary schools in the northwestern part of the state of Baden-Wuerttemberg. The cognitive, creative, and social capabilities of the selected students are far beyond the secondary-school average. The seminars are located in the three cities of Heidelberg, Mannheim, and Karlsruhe. Two teachers head up each project, which take place once a week in 2-hour sessions. Since 2001 approximately 600 students have participated in the Hector Seminar.

The DLR_School_Lab Oberpfaffenhofen is strongly involved in Hector Seminar activities and, as described earlier, has conducted four enrichment projects, such as robotics in 2004 (Space Robotics), geophysics in 2006 (Geophysics and Satellite Remote Sensing), satellite navigation in 2008 (GPS Einstein), and–again robotics in 2010 (Remotely Controlled Roboting).

The Program Evaluation Study “Hector Seminar”

The efficiency of the Hector Seminar program was thoroughly investigated in the framework of a long-term (8-year) longitudinal evaluation study following the context–input–program–product (CIPP) evaluation scheme developed by Stufflebeam (2000). The core elements of this study are as follows:

- A long-term observation of two Hector Seminar groups throughout their secondary school career (2001–2008).
- A two-stage selection procedure; the first stage selection is a screening process, whereas the second stage selection is based on the Munich High Ability Test Battery developed by Heller and Perleth (2000/2007, 2008).
- An experimental/training/control group design where the Hector Seminar (training) groups of each cohort consist of the 60 German gymnasium (college prep) students ranking highest (top 1%) on the test scores, and the control groups are formed from the 60 students ranking next; that is, the capabilities of both groups are roughly comparable. For more of the sample and evaluation details, see Heller et al. (2010).

The overall result of this study confirms the validity of the search for talent and the efficiency of the Hector Seminar program in all details. The most noticeable effect is the top ranking of both groups in their final school examination; however, the training groups outperformed the control groups considerably. The corresponding study options of the training groups in particular show strong preferences for the MINT disciplines; that is, the program fulfills its most important objective.

Because the four enrichment projects of the DLR_School_Lab Oberpfaffenhofen are considered essential contributions to the Hector Seminar, the geophysics project (Hausamann et al., 2009) has been included in the final evaluation report (Heller, 2009).

An analysis of the Hector Seminar project Remotely Controlled Roboting has recently been published by Piffer and Taulien (2011). It confirms the high abilities and motivation of the students, a strong increase in their key competencies such as management and teamwork, their ability to critically assess their work and progress, and their great interest in continuing their work and research in the respective subject.

In summary, the evaluation results for the Hector Seminar and its projects may also be considered a strong indicator of the effectiveness of the out-of-school lab concept.

TEACHER EDUCATION AT THE DLR_SCHOOL_LAB OBERPFAFFENHOFEN

The DLR_School_Lab Oberpfaffenhofen offers advanced training courses for teachers in order to prepare them for their class visits. The main objective of the teacher training is to help them to integrate the extracurricular activities into their standard curricula and thereby generate an application-oriented concept for classroom education. The out-of-school lab offers special courses for teacher groups from individual schools, for regional teacher groups, and for the advanced training of Bavarian seminar teachers; that is, the instructors of future teachers.

The key elements of such a teacher training are self-contained experiments, where the teacher adopts the role of a student and experiences the same feeling of success when completing an experiment. The experimental work is complemented by didactic as well as scientific background information about the respective experiments and research areas; that is, the teachers also learn how to connect the experiments to the school curriculum.

Since 2003, about 1,250 teachers have attended advanced teacher training courses at the DLR_School_Lab Oberpfaffenhofen. The general feedback from teachers has been positive, especially with respect to independent accomplishment of high-tech experiments, technical advancement, and stimulation for practical classroom teaching. Several of them were motivated to visit the DLR_School_Lab Oberpfaffenhofen with their classes. Consequently, as of 2011 this out-of-school lab has been fully booked 18 months in advance.

The feedback shown in Table 3 was collected in nine advanced teacher-training courses with approximately 140 participants between 2009 and 2010. The results show a high (close to 100%) acceptance of the overall concept of the courses, the quality of presentations and organization, and the competence of the instructors. The usefulness of

TABLE 3
Evaluation of General Comments From 138 Teacher Questionnaires (2009–2010)

Item	++	+	*o*	−	−−	*total*	*% (++ and +)*
Overall assessment of course	103	36	1	0	0	140	99
Presentation	110	30	1	0	0	141	99
Organization	94	40	3	2	0	139	96
Usefulness for school lessons	31	82	25	1	0	139	81
Competence	108	29	1	0	0	138	99

the course for school lessons was assessed more critically by about 20% of the teachers. Because the experiments were defined by research topics and not by the school curriculum, the high acceptance of 80% was certainly not expected.

Education of Teachers of the Gifted

Teachers play a key role in gifted education. Their distinguishing characteristics and necessary competence were summarized by Seeley (1985). Especially in Type III enrichments, the teacher's role changes from that of an educational instructor to that of an initiator, mentor, supervisor, coach, consultant, and assessor of achievement.

It is most important to support the independence, motivation, and creativity of gifted students (cf. Cropley & Urban, 2002). Pedagogical concepts such as self-regulated learning (Fischer, 2004) are ideally suited for Type III enrichment projects.

The teacher education concept developed at the DLR_School_Lab Oberpfaffenhofen (Hausamann, 2008), which interconnects out-of-school labs and the school curriculum, including independent experimentation, science background, and didactic context, utilizes all of the methodologies previously described and is therefore especially suitable for teachers of gifted learners. In addition,

- The scientific background of individual experiments easily can be extended to possible problems and questions typical for highly interested and talented students.
- Possible combinations of different experiments and technologies are addressed.
- The didactic background for accelerating experiments—that is, how to make them feasible and interesting for younger students—is characterized.

A 1-day workshop of a group of seven Hector Seminar supervisors at the DLR_School_Lab Oberpfaffenhofen in December 2004 is a typical example of such an advanced gifted-education teacher course. This workshop had been initiated by the Hector Seminar as a consequence of the first common space robotics project. The feedback was quite enthusiastic; the overall grade given by six of the seven participants in this workshop was "excellent." So far, it has been the nucleus of three follow-up Type III enrichment projects: geophysics in 2006, satellite navigation in 2008, and robotics in 2010 (as discussed earlier).

The DLR_School_Lab's extracurricular gifted-education concept is also integrated in the further education courses for teachers offered by the International Center for Giftedness at the University of Münster, Germany (ICBF, n.d.) leading to the so-called ECHA Diploma Specialist in Gifted Education. Since 2007 the potential of extracurricular science labs—such as the DLR_School_Lab Oberpfaffenhofen—in gifted education has been presented as part of the practical education block, the main focus being the conception of Type III enrichment projects and stimulating recommendations and proposals. Additionally, the DLR_School_Lab is an official observation location for observation of gifted student courses. Two observation periods are mandatory for each ECHA Diploma applicant.

SUMMARY AND FUTURE PROSPECTS

An enrichment concept for gifted students has been developed and successfully realized in numerous projects at the DLR_School_Lab Oberpfaffenhofen. The same holds for the gifted-education teacher-training concept, which includes the scientific and pedagogical basics for Type III enrichment projects at the pre-university school level.

Existing evaluations and assessment studies indicate that the concept of extracurricular science labs is successful; that is, the students' interest in science and technology is increased. However, there is still work to be done, especially in two areas.

First, the effectiveness of out-of-school labs should by investigated in studies involving a standard control-group approach. This will require long-term observations and a rigorous method to separate students who were able to visit out-of-school labs from students who were not. It will certainly take several years to answer the key question of what is the measurable impact of out-of-school labs on study decisions or on the corresponding STEM labor work force. As mentioned earlier, the University of Würzburg has proposed a study based on a control-group design and comprising several out-of-school labs in Bavaria, in which the long-term influence of extracurricular science labs will be investigated.

Second, the enrichment projects have practically demonstrated how school students, by working with scientific subjects far above school level, are transformed from learners to researchers. The transformation of concepts such as self-regulated learning to a corresponding concept of self-regulated research would certainly help to describe the crossover of gifted young people from school to university. In this transformative process, the spatial, social, and formal boundaries of the classroom situation are dissolved; problems are no longer limited to the known, thus requiring new processes of cognition. From the author's point of view as a practitioner it would be highly desirable for the theoretical description of the transition from a gifted learner to a gifted researcher to be addressed in future giftedness research.

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