# Paving the Way for Computer Science in German Schools

Ulrik Schroeder(✉), Nadine Bergner, and Thiemo Leonhardt

Learning Technologies, RWTH Aachen University,
Ahornstraße 55, 52074 Aachen, Germany
{schroeder,bergner,leonhardt}@informatik.rwth-aachen.de

**Abstract.** There is an ongoing discussion in Germany, whether and to what extent computer science should be integrated into school education as a mandatory subject on the level as natural sciences. The goal of this article is to present scientific evidence of effects of computing interventions of extra-curricular services offered by universities as supplement of the currently missing school integration.

**Keywords:** Extra-curricular computer science education
InfoSphere · go4IT!

## 1 Introduction

Worldwide, there is an ongoing controversial discussion with regard to the importance of Computer Science Education (CSE) and more particularly its lack of presence in pre-college education [1]. In this article, the authors present arguments, research results and projects that (a) taking up informatics as a mandatory school subject at least from lower secondary level on is recommendable, (b) there are very good concepts and examples to teach informatics, (c) from early ages on, and (d) especially girls and young women can profit.

Computer Science (CS) has both enormous educational benefits (logical thinking and problem solving skills, understanding a world enhanced with digital technology), and economic benefits (as a modern workforce depends on far reaching IT-skills). It should be part of every student's education, just as natural sciences are, especially, because utilizing the digital world becomes more and more important in all fields of life, not only in the IT sector itself.

It is crucial to distinguish between Computer Science as a rigorous subject discipline on the one hand, and IT applications and/or digital literacy on the other. Computer Science has its own body of knowledge, established methods and techniques, and thinking skills, which will last students a lifetime [1]. The core skill-set of Computer Science is independent of new technologies and programming languages. Programming is central to computing, but the underlying principles of algorithms, data structures, and computational thinking skills are both more fundamental and more durable [2]. On the other hand, ICT education


H.-J. Böckenhauer et al. (Eds.): Hromkovič Festschrift, LNCS 11011, pp. 590–609, 2018.
https://doi.org/10.1007/978-3-319-98355-4_34

covers knowledgeable fluency with computer tools and the internet. Due to the prevalence of informatics systems in the all-day life of children, both subjects are essential and should be taught in primary and lower secondary education.

The Joint Informatics Europe & ACM Europe Working Group on informatics education presented strong arguments for teaching informatics as early as possible, preferably in primary schools. "[...] European nations are harming their primary and secondary school students, both educationally and economically, by failing to offer them an education in the fundamentals of informatics." [2, p. 17]. Although associations like the German Association for Informatics (GI) have argued to include informatics in general education since the late 1980s and published diverse recommendations for principles and standards for CSE [3–7], the German educational system falls back behind that of other nations. In view of the widespread digitalization, in many countries, CSE in primary or secondary schools has reached a turning point, shifting its focus from ICT-oriented to rigorous computer science concepts [8–13]. One of the existing challenges in these countries though is CS teacher (further) education. In Germany, there is a quite solid CS teacher education program [14], but the broad implementation of CS as mandatory subject in lower secondary schools is still missing and thus, too few students take up the subject.

As long as informatics is not a school subject comparable to the natural sciences, there are many universities offering extra-curricular activities teaching various aspects of informatics ranging from targeting pupils from primary to lower and upper secondary education. At ETH Zürich Hromkovič has established LOGO courses [15] for primary and lower secondary students and worked out teaching materials [16] based on Papert's original ideas [17] and focusing on the essential core of what computer science means for human culture [18]. In the following, we present our own comprehensive activities at RWTH Aachen University, namely go4IT! [19,20] and InfoSphere [21,22], and the underlying research [23] which lead to their conception and design.

## 2 go4IT! – How to Raise Girls' Interest for Computing

### 2.1 Motivation for go4IT!

A positive effect of an early access to informatics could lead to increasing the interest for technology, preparing children for computational thinking and fostering problem-solving strategies in general. Interest for technics and new developments definitely exists in primary schools and should be promoted as well. Especially the girls' interest for technical subjects like informatics should be stimulated at that age, as their interest diminishes during puberty and – maybe therefore – they were often neglected in respect of technics so far [1].

To foster young girls' interest in informatics RWTH Aachen started the project go4IT! in 2009 [19,20]. Since then, 284 workshops have been conducted in which more than 3.700 girls in the age 11–13 took their first steps in programming robots and computational thinking. The concept was based on the Roberta project (2003–2006) [24]. The BMBF-funded project Roberta Project of Fraunhofer IAIS (Institute for Autonomous Intelligent Systems) focused on gender-sensitive course concepts in didactic implementation and planning. In a second funding phase from 2005 to 2008, the project was funded by the European Union under the title "Roberta goes EU" for the transfer of concepts. Within the projects Roberta Centers were established, but no further efficacy studies were carried out after the first phase of the project [25].

The following assumptions were derived from the results of the Roberta project. A sustainable change in girls' self-concept through gender-sensitive robotics courses, including the gender difference, must be geared towards offering longer courses that go beyond a typical short workshop offer, as is customary at GirlsDay events. The didactic-pedagogical concept is based on increasing difficulty of the tasks while at the same time maintaining the motivation. Consequently, a particular value is attached to a variable schedule and aids for adjusting a current course are to be provided. The voluntary nature of participation decreases with longer courses in importance for effectiveness. Longer courses are therefore also suitable for participants who are previously not interested in STEM topics.

Additionally, instead of having girls to visit Roberta centers, go4IT! teams actively visit all high schools in the greater Aachen Region to offer two-day workshops in their premises. At the schools, an enthusiasm for computer science and technology should be transferred to the pupils, the parents and the teachers. The intervention course go4IT! is anchored in school-based profiling and thus brought into the consciousness of the school community. This takes pressure off girls, who are easily exerted by the peer group, when individual girls (for example, the only one in a class) express their interest in STEM, especially in computer science.

The main results of the dissertation of Leonhardt [26] for the conceptual refinement, design, and scientific evaluation of go4IT! are summarized in the following two subsections.

### 2.2 Theory-Based Design and Evaluation of go4IT!

Different gender-specific behaviors of (baby) girls and boys are recognizable by parents from birth, and present themselves in more stable emotions for girls, and higher irritability and impulsivity for boys [27–29]. However, research into the differences in the development of interests, attitude, and professional orientation, or even their origin, has not yielded any unambiguous results [29]. As Mammes notes, the approaches in gender research are controversially discussed and, in the case of a comparison of purely biological causes to purely sociological causes, can even be described as antagonized [30].

Therefore, these differences lead – amongst others – to a significantly smaller representation of women in computer science and other technical disciplines. Numerous measures and initiatives try to introduce girls, adolescents and young women to computer science. Nevertheless, since the reasons for these gender-specific differences are still mostly unclear, most measures lack a scientific basis.

The analysis of the state of research on measures to increase the number of female computer science students yielded a research controversy on the causes of gender differences. An examination of these causes has been essential with regard to the legitimacy and theory-based development of gender-specific support measures in the go4IT!-project.

It is obvious that there are biological differences between the sexes and it is indisputable that different behaviors at different stages of development can be observed. However, the interpretation of an implied biological gender difference as a basic assumption for gender-specific behavior in interaction with the environment is not detectable: neither by consideration of hormonal and genetic differences nor by theories about evolutionary selection. Stereotyping and thus accepting the social gender role in adulthood and the biological effects of hormones in physical and cognitive development form a complex interactive system capable of describing the current self, but the causes of gender differences seem inadequate. The question of the causes of gender differences remains scientifically largely unanswered and does not provide a suitable basis for constructively solving the problem.

Research findings on gender differences in the cognitive area are marginal, so that currently the thesis of gender equality in the cognitive area is plausible. Crucial cognitive differences are hard to detect or, as in the case of the gender difference in mental rotation (ability to mentally rotate two- or three-dimensional objects) can be quickly adjusted through training interventions [31]. Measurably large differences can be found in the motor skills and in basic psychological constructs. For the investigation of a persistent interest of a person in computer science and technology, the self-concept, the self-efficacy and the locus of control convictions in dealing with technology have been the most relevant psychological constructs [17,32].

From the point of view of pedagogical psychology, the formation of a dispositional interest in a person is a multiphase process that presupposes repeated activities with the object of interest. A negative attitude in self-efficacy (negative assessment of one's ability to reach a certain goal) and locus of control (expectation that the outcome does not depend on one's behavior or condition) is expressed in a weak self-concept in relation to the subject matter. A weak self-concept counteracts a continuous engagement with the object. The development of a dispositional interest in the subject is thereby severely impaired.

An intervention to promote a technical and informatics-related dispositional interest should therefore first foster the development of a positive self-concept. Increasing and stabilizing the interest development can then be done secondarily or subsequently – under the more favorable condition of an already positively influenced self-concept [33].

Utilizing tangible learning objects take away the fear of not being able to understand new commands, and has a positive effect on the participants' confidence in the examined setting. Hence, in groups with little prior knowledge tangible objects are preferable over virtual [32]. The advantage of a virtual learning object is the willingness to use unknown commands and, with increasing

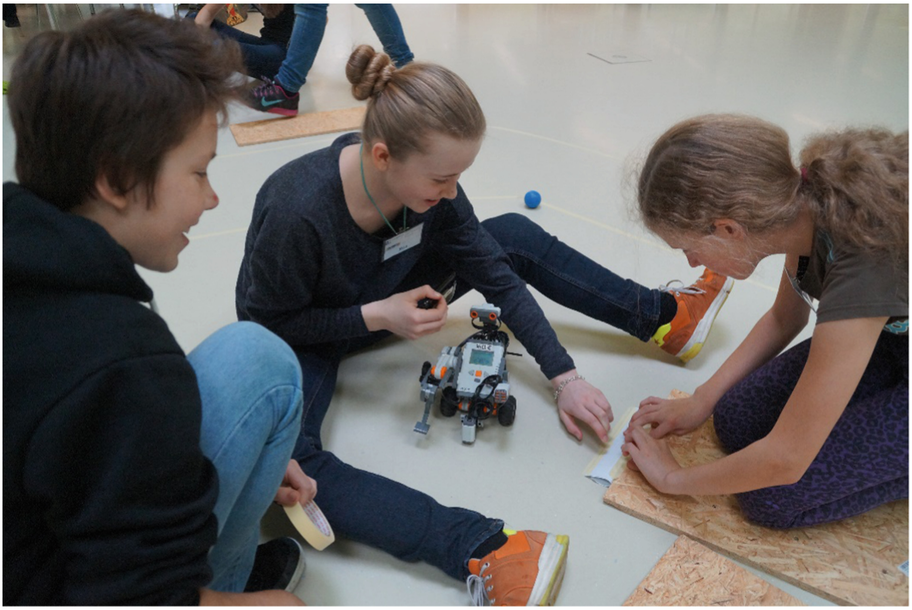

**Fig. 1.** Designing and programming robots and their environment during go4IT!-workshops

complexity of tasks, can lead participants to try new approaches and to try new commands and constructs rather than a real learning object. According to these results, virtual learning objects make sense as a subject of study for in-depth courses [34].

### 2.3 Resulting go4IT! Design

Taking into account the deficits and conclusions described above, a two-step approach was developed. The first phase consists of a 2-day intervention workshop in the 6th and 7th grades (late childhood, age 11–12) for 12 to 14 girls in their schools (see Fig. 1). The choice of location aims at reaching girls who would normally be shy to independently take up an extra-curricular offer. Two students (at least one female) supervise the workshops acting as assistants and role models. The supervising students are trained in the practical application of the didactic principles of a reattribution training. This includes commenting on observed performance results with desired attributions, verbalizing desired attributions through a gender-neutral model, and, to a lesser extent, reinforcing favorable cause statements. There are almost no instruction phases. Students actively explore the commands for programming the robots.

During the workshop, the girls build Lego robots and program their behavior in a textual language NXC (not eXactly C) by reading sensor values and controlling different motors. In the end, they solve self-imposed tasks such as finding a path out of a labyrinth. Utilizing a textual programming language instead of a visual programming environment like Scratch has the advantage that the girls perceive it as real programming instead of clicking and playing with robots. They are proud having achieved the programming and tell the boys in their classes.

In the second phase, a follow-up workshop deepens the first and links to everyday life of the participants, who experience technology as designable and useful. The participation is voluntary, which corresponds to the phase of an emerging individual interest according to [35]. Carrying out the construction workshop over a longer period of time (4 days) as well as external special location support the repeated occurrence of a stabilized situational interest according to [36]. The psychological construct "fun" positively influences the subject-related emotion and in turn the development of an emerging individual interest. This link to fun has a significant impact on professional decisions [37]. Promoting autonomy, competence experience, social inclusion as well as the personal significance of the subject matter all support the formation of a stable personal interest among the participants.

In order to influence the control variable environmental socialization after the two workshops have been carried out, the parents of the children are included in the final stage of the second workshop.

Currently, we offer two different follow-up workshops, one during Easter vacation, and the other during the autumn break. In the first, titled "CS designer," the girls design and program clothes and accessories with technical finesse utilizing microcontrollers (Arduino Lilypad), lots of LEDs and conductive yarn. The girls take home their unique items for further development an enhancement of their programming skill in school lessons, study groups or privately. The autumn workshop focusses on programming their first App for a smartphone as a remote control for the robots, which then can be controlled for a complex choreography such as robot group dances, a robot marriage or playing roles in modern fairy tales in the final presentation with parents and siblings.

The questionnaire-based empirical pre- and post-study of the intervention workshop, together with the pre- and post-examination of the follow-up workshop, gave insights regarding the stabilization of effects on the technical self-concept as well as the related self-efficacy expectation and the locus of control in dealing with technology. In addition, a possible effect on a future perspective in the field of computer science has been examined.

In detail the following research hypotheses are examined: 1. The locus of control in dealing with technology and the self-efficacy expectancy in dealing with computers and technology and the future perspectives in the technical and informatics area. 2. The change on these variables by the action of an Intervention workshop involving the environment of Participating. 3. The updated actual state with respect to these variables in the Participation in the follow-up construction workshop. 4. The change in terms of these variables through the Follow-up construction workshop.

The non-parametric Wilcoxon signed rank test for connected samples has been used over the parametric t-test because the differences between the post- and pre-tests are not sufficiently normally distributed and the items are ordinally scaled. To interpret the measure of a possible effect, the effect size ($r$) is used in relation to Cohen's criterion. The significance is given as $p$. The test statistic $U$ is calculated as the minimum of the negative and the positive rank sums [38].

There is a high significant improvement in the group of participants after the treatment intervention workshop with high effect size ($U = -13.012$, $p < .001$, $r = -.55$) on the self-efficacy in the use of computers and technology. This change was found in the entire sample (medianpre = 2.3333 and medianpost = 2.0000, while strong shift of the lower and upper quartile in the same direction). On locus of control scale, a high significant positive change was seen after the treatment with mean efficacy ($U = 6.418$, $p < .001$, $r = -.29$). The shift is evident throughout the sample. The future perspectives in the technical and informatics area changed after the treatment high significantly with a mean effect size ($U = -7.512$, $p < .001$, $r = -.325$). The median remains the same and the shift is in the upper two quartiles in the intended direction. Accordingly, it has not changed the overall group's attitude in the future perspective, but above all those participants with a previously more accurate or complete rejection of a future perspective in the informatics-technical field.

On the self-efficacy in dealing with computers and technology, only a significant small effect in the intended direction could be measured in the follow-up workshop ($U = -1.746$, $p < .041$, $r = -.24$). This is explained above all by the very strong self-efficacy of the participants in the follow-up workshop. The analysis of the change in the locus of control in dealing with technology did not yield any results. The future perspective changed in the group of the post-treatment setup workshop with a highly significant mean effect in the intended direction ($U = -2.663$, $p < .01$, $r = -.369$).

**Sustainability of Interest.** Despite the large number of projects that seek to promote STEM, there still is no long-term effect on study choice behavior, especially for women [39]. This is a future-endangering development, especially in our increasingly technological society, since access to the design of the STEM area is thus open to only one – predominantly male – part of the population.

According to Renn [39], essential deficits are the lack of entanglement of various measures and the lack of continuity due to financial problems and didactic deficits. Since there are only few subject areas from adolescence, in which a deeper personal interest is built up and maintained, interventions for the development of technology interest have to be made early in the development of children. This applies in particular to girls with a steadily declining interest and corresponding low self-concept towards STEM in lower secondary education [40].

From a system-theoretical perspective, the two phenomena of neutralization and dyssynchrony explain the lack of long-term effects on the self-concept and the self-efficacy expectation after interventions [33]. Neutralization describes the negative effect of the permanent control environment on the effect of the intervention. The effect of an intervention can be neutralized despite the proven short-term effects of the non-environmental factor. The environment as a control variable is subdivided into the two core areas of school and family in child development. Children spend much of their time at school. In addition to school education, they get to know gender stereotypes here as well as in their private environment, go through their puberty and solidify their attitudes. The behavior of the teachers and the design as well as the perception of the lessons have an effect on the subject-specific attitudes and on the professional career taken. According to [41], the assessed teaching quality of the subject closest to the later study option has a strong impact on the likelihood of starting a corresponding course. This underlines the important role that teachers can play in students' career choices.

A partial change of a system is not enough, so that the entire system permanently shows the desired behavior. To avoid dyssynchronies, it is important to offer promotion on a continuous basis. This lead to the foundation of the extra-curricular student lab InfoSphere at RWTH Aachen University, which is described in detail in the following section.

## 3 InfoSphere – Extracurricular Student Laboratory for Computer Science at RWTH Aachen University

### 3.1 Motivation for InfoSphere

The main goal for founding InfoSphere [21,22] as the learning lab for computer science at the RWTH Aachen University in 2011 was to strengthen students' stable interest in informatics through subsequent interventions on a regular schedule. InfoSphere currently offers 35 workshops, ranging from few hours to several days and addressing children and adolescents between 7 and 19 years, or in the case of family events even younger children up to their grandparents. The workshops promote the often under-perceived aspects of computer science such as creativity, teamwork, and its impact on everyday life.

**Overview.** InfoSphere offers different approaches to various facets and applications of computer science for children and teens covering all school grades. There are half-day and full-day modules as well as modules that stretch over several days. Modules contain research- and 'Puzzle'-projects and, above all, hands-on experience. Many of the modules were designed for lower secondary students, so that no prior knowledge is required, and can be booked for every grade. Some of the modules can be easily integrated into high school computer science classes, to broaden the knowledge on covered topics with a field-trip or as an alternative to in-class teaching. For these all learning materials are available as open educational ressources (OER).

**Goals.** The main goal of InfoSphere is to strengthen students' self-efficacy and locus of control as well as concrete competences to utilize and design technology for a range of tasks. Students are to explicitly perceive their own skills in analysis and design by utilizing methods of computer science. They work on open tasks, which require creative solutions in teams. InfoSphere is one of very few student laboratories, which do not just bother with applications, but with the core of computer science. The goal is to uncover concepts, methods and tools of computer science, which are normally hidden in everyday life applications.

**InfoSphere Concept.** The student lab is open to every level of education (all types and classes of schools) and computer science workgroups. It picks up current topics of computing in a different setting with modern devices (tablets, smartphones, computing toys and gadgets, microcontrollers and learning games), which cannot be experienced at school. Thus, subjects are more appealing and more impressive to students. They are directly connected to their life (e.g., smartphone-programming, GPS systems, social networks). They extend their point of view towards new and fascinating subjects like visual cryptography, the limits of computer-calculable problems, and other current computer science research topics.

Most of the modules can be completed independent of a computer science course, but even greater effects can be achieved if workshops are embedded in school courses. In order to allow teachers to embed workshops into their course plan module handbooks describe the compatibility of every InfoSphere module to the official curriculum (NRW-Informatiklehrplan).

InfoSphere modules additionally strengthen media-competences. Results of projects and experiences are documented in form of a community on our website and are made available for other students. Project results can be presented to non-participants like parents, fellow students or other teachers. This is most interesting when the topics are taken up in school lessons. Pupils are given access to a new platform, on which they can continue to pursue the topic and interact with fellow interested students.

Current CS research topics are also addressed to expose students to the world of a university and give them a first impression of research.

InfoSphere has drawn more than 9.800 students, presenting various facets of informatics and computational thinking; see Fig. 2. Again, scientific studies accompanied the conception, design, and development. In this case the research focused on factors to form and develop students' notion of computer science as a discipline. The main results of the corresponding dissertation are presented in the next section.

### 3.2 Theory-Based Design and Evaluation of InfoSphere

In her dissertation [23], Bergner investigated the prevailing public image of computer science – especially the one of children and adolescents – and analyzed it for typical misconceptions. She designed interventions in the extra-curricular student lab InfoSphere in order to shape prevailing images towards a more realistic picture of the discipline. Having the wrong imagination of what computer science is and what competences and skills need to be learnt is seen as one obstacle for students to (a) pick up the topic as career choice, and (b) successfully finish CSE in middle schools as well as universities.

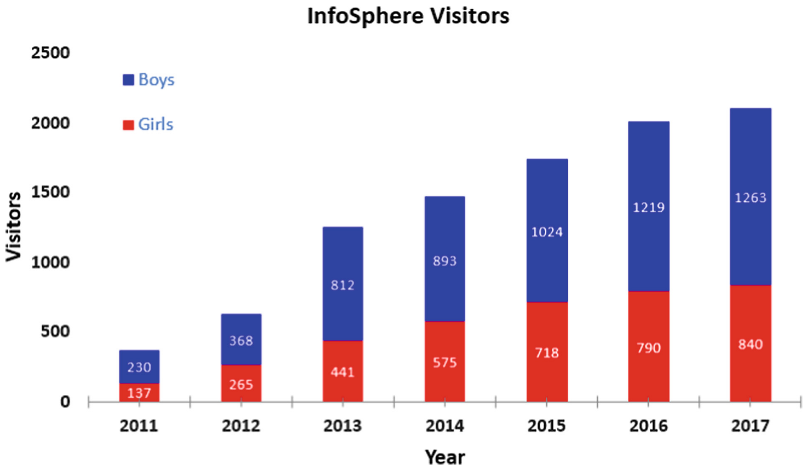


**Fig. 2.** InfoSphere workshops have been conducted with 9.800 students. There is an even higher demand, which is only limited by spatial and staff capacity.

Several studies concerning the overall concept of InfoSphere, design criteria for extra-curricular CSE interventions, and factors that influence the image of the discipline have been conducted. Overall, interesting differences were found between the sexes, in terms of both expectations for the visit to InfoSphere, and in terms of their ideas about the computer science discipline and IT professionals. For example, girls see the technical aspects of computer science in the foreground more than their male peers do. This statement, coupled with the fact that girls especially feel that the technical aspects are of little interest, can already be seen as a factor contributing to the low number of women interested in computer science.

**Overall Goals of InfoSphere.** Five main goals have been pursued when building the computer science learning lab InfoSphere at RWTH Aachen University:

1. All students have the opportunity to get to know the full spectrum computer science and its applications.
2. Visitors can actively and individually explore the world of informatics (thus its name); see Fig. 3.
3. Raising interest in informatics should occur as early as possible in order to counter public misconceptions and prejudices concerning the discipline.
4. Interventions are also addressing previously (seemingly) not-interested children (and especially girls and female adolescents) to give them a realistic insight into informatics in order to prepare well-grounded decision of whether to choose the subject, e.g., as elective in middle school.
5. Courses on all levels and for all ages are to continuously accompany students throughout their school time and lead to a sustainable development of interest and well considered decision of career choices.

Bergner could show via various qualitative and quantitative studies that the objectives 1, 4, and 5 have been achieved with InfoSphere modules. She found a greater diversity and a stronger content-related proximity to the notion of informatics concepts in the free text answers in the post-test (1) The high demand for workshops especially by primary and lower school classes, lead to the conclusion that students with previously no or few interest for computer science were reached (4) Additionally, the steadily increasing numbers of private registrations by multiply recurring students affirm that objective 5 is well addressed. Concerning (2) no conclusions can be drawn from the existing data. Only goal (3) show contradictory effects: While the interest of some students, especially the younger ones, could be increased, on average a small decrease has been perceived.

The sample of Bergner's studies included 2123 valid records, of which 1758 could be paired correctly. Thus, she evaluated pre- and post-test data of 879 visitors, of which 308 were female (35.0%) and 571 male participants (65.0%). It should be noted that among the visitors of the upper secondary level, the proportion of women drops to only 21.1% (compared to 41.1% in lower and middle grades). Furthermore, most of the visitor groups from the 8th grade visited InfoSphere as part of their computer science education. Overall, therefore, there is a dependence between age and gender as well as to having received computer science lessons in school.

**Factors for Designing Extra-Curricular Interventions.** Main findings show, that modules not relying on previous knowledge are favored. Modules with a strong reference to everyday life or those with materials and media not available in the average school context (i.e., smartphones, robots and microcontrollers) had a larger demand; see Fig. 3. A majority of participants reported in the post-test an increased interest in the cultural and sociological impact of modern technology and computer science methods (i.e., encryption algorithms).

The didactic design with two or three tutors (ideally with role models for both sexes) fostering individual and active exploration in teams, as well as rich mix of methods and presentations with modern devices has been evaluated very positive by students, teachers and parents. Participants acknowledged a high fun-factor for each of the 20 evaluated modules.

The difficulty level of a module had a great influence on almost all other ratings. A module rated as too difficult leads to low scores in interest for the topic, motivation to come back, perceived fun and even rating of tutors or materials. In contrast, too easy modules had nearly no loss in motivation, which leads to the conclusion that expecting too much of the students must always be avoided. Challenges on the other hand help the students to increase their performance and if applied correctly are the key to increase long term motivation.

**The Prevailing Image of Computer Science.** The mainly quantitative evaluation with regard to the students' conceptions about the discipline was implemented by means of an online-based pre-post-test design. After pre-tests and a first study, a second period – from November 2012 to December 2013 – 116


**Fig. 3.** Active exploration in teams with individually defined tasks is fostered

complete records of primary school children, and 879 responses from students of lower and upper secondary classes were evaluated. Measurements were made on the prevailing image of computer science (pre-test), as well as the changes triggered by an intervention, in particular the effect of various modules (comparison of pre- and post-test). For both evaluations, the participants were divided into subgroups of girls and boys, different age and school levels as well as those with and without previous informatics schooling.

*Informatics Being Purely Concerned with Computers.* The analysis of (up to) three free-text answers associated with the discipline revealed – analogous to the results of previous investigations – that computer science is often seen as only concerned with the computer. The term “computer” with 908 of the 1414 answers (64.2%) was clearly named most frequently. This is not as self-evident as it might seem, because in German the discipline is named informatics and not computer science, which is a misleading term. Also in the ranking of given terms, the term “computer literacy” has been chosen consistently for all subgroups as the top notion.

*Informatics = Programming.* The prejudice that computer science is synonymous with programming was also evident in a majority of students. The number of mentions of the term “programming” is highly dependent on the respective school level. While lower secondary students hardly mention programming, upper level students strongly focus it with 201 mentions (52.3%) only just behind the term “computer” with 207 votes (53.9%). The vast majority of the upper level students had CSE in school. Still, almost all visitors associate the job description of the computer scientist strongly with that of a programmer.

*Girls Less Confident than Boys.* Although overall it could be shown that the estimates for the confidence of the own image of the computer science are nearly normally distributed, nevertheless significant differences resulted between the sexes and also the age groups. Overall, girls felt clearly less confident with their conception. As a result of the lesser experience, younger pupils are much less confident than older students.

*Interest Independent of the Subgroups.* Although the gender-specific numbers of students suggest a different assumption, the preliminary survey shows that girls find computer science same as interesting and exciting as boys. In addition, the interest in computer science, as well as the assessment of the attributes "versatile" and "exciting," are independent of having been schooled in computer science. However, the school-level-specific evaluation shows that high school students (having had CSE in school) consider computer science to be less versatile than those from lower levels, which reveals that computer science education at schools does not always cover the entire spectrum of computer science.

*Girls See No Future for Themselves in the Field of Computer Science.* However, in terms of importance for the later professional life and the willingness to deal with computer science aspects in the future, there are significant differences between the sexes. Girls can imagine far less about dealing with computer science in the future than boys. Also, girls rank the influence of digitalization on their own later professional life far smaller than their male classmates. In order to find out the reasons for these divergent assessments, it is necessary to shed more light on the other questions on the image of computer science.

*Computer Science (Still) a Male Subject.* Although both sexes have a clear tendency towards CS being a male subject, it should be noted that – contrary to several studies by other authors – girls in the InfoSphere sample consider it significantly less male than boys.

*Computer Scientist Are Socially Not Well Integrated.* The presumed lack of social integration might explain why most students did not see their future in the field of computing. Especially girls and pupils without informatics classes doubt that computer scientists have (many) friends.

*CS Is Not Creative.* The same subgroups judge the profession of being not creative. Most girls do not link skills in solving complex problems with computer scientists. No groups recognize that utilizing methods of CS can create innovations.

*Importance of Technology.* In addition, the given free association of computer science terms revealed that female participants in particular strongly focus on the term "technology" (20.4% of girls versus 9.8% of boys). Gender comparisons show that boys give more room to aspects such as "teamwork" and "intelligence," while girls stronger emphasize the aspects of "understanding technology" and "programming."

*Expectations on Computer Science Lessons (or Study Programmes).* Lower secondary students who choose the elective show an interest "in computers" (probably more precisely in applications running on it), whereas counterarguments are diverse. In secondary education, on the other hand, most students take up the subject, if they plan to study CS at collegiate level.

*Further Gender Differences.* For the workshops girls are much more likely to desire clear guidance. This can be explained by often greater uncertainty and lower previous experience with informatics and computers. Only 46.9% of girls have previous knowledge from any kind of computer science education, whereas 81.7% of boys do. In addition, girls prefer to work with (many) different materials, whereas boys are more computer focused. This difference can also be explained by the different previous experiences with the computer medium. In order to address both genders equally, it is important to find a balance between plugged and unplugged CSE.

*Impact of Computer Science Education.* Students with computer science lessons rank concepts such as "logic" or "problem-solving" much higher than those without CSE. Additionally, this subgroup perceives the social relevance of CS consciously.

*Age-Dependent Effects.* Younger students link the ability to "explain well" with computer scientists presumably by transferring the observed competence from computer science teachers (or tutors in InfoSphere).

Overall, the analysis of the prevailing image of computer science, shows that

- the age, the school level, having received computer science education and above all the gender of the participants of the studies have a great influence on the prevailing image of computer science,
- above all the description as "science purely concerned with computers" and the equalization of computer science with programming are widespread prejudices,
- girls, even stronger than boys, are uncertain about the correctness of their image of CS,
- although there is generally no gender-specific interest in computer science, girls show less interest in almost all aspects of computer science topics,
- girls for themselves rarely see a future in or with computer science and
- the prejudices of the male computer science and the low social integration of computer scientists are still present today, albeit less pronounced than in previous studies.

**Factors Leading to Transforming the Image of Computer Science.** In order to evaluate the changes that were triggered by having taken at least one of the workshops in InfoSphere, on the one hand module-independent analyzes of the entire sample and on the other hand specific analyzes of the most frequently evaluated modules were carried out.

*Broadened Image of Computer Science.* The cross-module evaluations show strongly the image of computer science has widened. In the post-test survey, a total of 665 different terms were given, 24% more than in the preliminary survey. Most of the classical associations (e.g., "computer" or "programming") lost importance. The term "logic" was the only one of the top 10 mentions from the preliminary survey, which recorded an increase. The previously highly ranked term "technology," especially among female visitors, has been downgraded in favor of other informatics aspects.

*Confidence Level.* A key change, especially in terms of the objectives, is in the confidence concerning one's own image. Boys and girls feel significantly more confident in their personal image of CS.

*Computer is a Tool.* The role of the computer is evaluated differently. It is clearly more often perceived as a tool and not as the (sole) core of computer science. In direct connection with this, students are far more convinced that computer scientists do not only work on the computer and do not exclusively program. Furthermore, the activity of repairing devices in the view of children and adolescents decreases significantly. In the ranking of the given terms the keywords "computer literacy" and "technical understanding" lose value.

*Decreasing Overall Interest in Computer Science.* Negative, however, is the (slight) decrease in the values of interest. Here it is to be hoped that just those children and adolescents have lost some of their interest, which otherwise would have opted for computer science under false beliefs. Nonetheless, in the future it will be necessary to further investigate the effect and make corresponding changes to the modules.

*Decrease in Relevance to Working Life.* Furthermore, the perceived significance for one's later professional life has decreased. One possible explanation is that for the majority of the visitors, the modules address completely new and previously unknown areas of computer science. As these go far beyond the publicly prevailing opinion on IT competences, it is understandable that at first glance these aspects seem less relevant for later professional life.

*Teamwork and Creativity.* In the apparent contradiction to the previous point more advocates for a compulsory subject computer science are found after workshops. Another clear success of the InfoSphere concept is that the stereotype of the men's subject has been significantly reduced, both among girls and boys. In addition, the concept ranking shows that the relevance of the terms "creativity" and "teamwork" has increased significantly. Thus, it has been possible to bring previously unnoticed concepts into the consciousness, whereas often cited stereotypes have fallen into the background.

*Social inclusion* is now also viewed from a different perspective: more students are now convinced that computer scientists can have (many) friends. Overall, computer scientists are no longer viewed as loners who sit in front of the computer all day.

The *interest in computer science* has been influenced by InfoSphere workshops. Previously ignored activities (e.g., “solving puzzle problems”) are attracting greater interest, whereas classical activities (e.g., “developing programs”) are falling in interest. The reason for these changes could be that classical activities seem to be less desirable, or that the other activities have simply become more interesting. In addition, there is a shift in interest towards the social impact of CS.

It is surprising that despite the clear preference for partner and group work after completing a workshop the *desire for individual work* has increased. This effect might be caused by the almost continuous work with other students on the one hand or by the fact that in teams, some technical devices (smartphone, etc.) or limited hands-on materials must be shared, what occasionally led to disputes.

The module-specific evaluation yielded more detailed insights into the aforementioned findings. Especially the module “treasure hunt” was able to clarify because of its didactic structure – the computer serves here as a pure aid – that computer science is more than pure programming. Already the free association task showed that this module strongly emphasizes the meaning of the term “logic” in relation to computer science. Directly related to this is also the increased visibility of theoretical aspects of computer science. Also, the module “First Own App” shows significant effects, as the ability or activity to repair computers is less in the focus of the students. Presumably the first contact with aspects of programming for the young target group lead to the increase of the perceived importance of the term “programming.” Unaffected by this, the perceived relevance of computer literacy decreases, so that it can be assumed that a new, broader picture of computer science has been conveyed.

The negative effects of the modules on the general interest of children and adolescents in computer science can be better explained by a detailed analysis of the two similar modules “InfoSphere goes Android” and “First Own App.” Above all, the level of tasks is crucial. For example, the more sophisticated module “InfoSphere goes Android” saw a significant decline, while the second module remained the same. The decline can therefore mainly be explained by setbacks during workshops.

The module “First Own App” is particularly effective against the cliché of the male subject, with the other modules also showing significant changes. A possible reason for this is the chosen context. The participants develop their own painting program, which should appeal to especially artistic-creative students and especially female students. In addition, observations during workshops show that female students in particular follow the given instructions very closely and thus achieve the goal without major setbacks, whereas students who are mainly trying out things more independent have difficulties in implementing their ideas with the App Inventor.

With regard to the social integration of computer scientists, which was originally considered very negative, the module “Treasure Hunt” shows the greatest success. Through the continuous and necessary teamwork throughout the module it is conveyed that computer scientists are networking and working in teams.

In addition to an increase in the question of whether computer scientists have (many) friends, above all the ranking of given terms shows that according to this module "teamwork" and also "creativity" have gained considerable relevance. A similar result in terms of teamwork is also observed with the module "First Own App," although the teamwork there is not mandatory in terms of content, but an exchange between the participants significantly facilitates the independent development of software.

Very positive are also the other changes to the image of computer science. For example, visitors to the module "First Own App" regard computer science as more exciting and diversified. After the module "Internet Game," some students state that computer science is now easier to understand. The participants gain insights into a hitherto completely unknown technique. These first experiences of success in understanding complex relationships probably lead to this shift. The module also emphasizes that computer science plays a major role in a large number of areas.

It is also interesting to see how the students' interests regarding informatics content and activities have changed. Thus, both modules for app development and also for treasure hunting lead to a significant increase in interest in social aspects of computer science. At the same time, the "InfoSphere goes Android" module is reducing the interest in "getting to know new technologies" and "programming." This can mean two things: either the interest in programming has fallen directly due to the challenges and setbacks of the module, or it has somewhat faded into the background in favor of other aspects. The module "First Own App" increases the desire to try different methods, to give presentations and to discuss different aspects. The modules "Internet Game" and "Treasure Hunt" help the puzzle tasks to become more popular. Only the module "Internet Game" causes among its young target group, that also the classical activity – understand the functioning of programs – gains in popularity.

Finally, a few special aspects of individual modules stand out. First, the use of the App Inventor (or other English-language software) is very profitable in conveying the need for at least basic foreign language skills. On the other hand, utilizing particularly interesting devices or hands-on materials during group work phases may lead to conflicts and envy. Third, the desire for more individual work came up in the evaluation of the modules "InfoSphere goes Android" and "Internet Game." That shift did not occur in the other modules. It might be explained by the fact that teamwork was considered obligatory, otherwise achieving the goal would have been much more difficult or even impossible.

## 4 Conclusion

For both of the RWTH outreach activities there is scientific evidence that CSE is possible in young ages and can have the intended effects. The go4IT!-project has been shown to raise interest in technology and CS. The program runs successfully since 2009. However, it is also obvious, that singular inventions can only start the process of wakening interest, which must be stabilized over iterations of activities, which build on the previous positive experience. Of course it would be optimal, if CSE could be implemented as mandatory school subject on the same level as natural sciences.

As long as there is no such school integration, further CSE experience in lower and middle school classes must be provided by extra-curricular services such as the ones by the computer science student lab InfoSphere. Again, effects concerning the image of CS as a discipline could be shown. However, a longitudal study to investigate effects concerning career choices are missing.

## References

1. Sabitzer, B., Antonitsch, P.K., Pasterk, S.: Informatics concepts for primary education: preparing children for computational thinking. In: Proceedings of the 9th Workshop in Primary and Secondary Computing Education (WiPSCE 2014), pp. 108–111 (2014)
2. Joint Informatics Europe & ACM Europe Working Group on Informatics Education: Informatics education: Europe cannot afford to miss the boat. Technical report (2013). http://europe.acm.org/iereport/ACMandIEreport.pdf. Accessed 28 Jan 2018
3. Gesellschaft für Informatik: Rahmenempfehlung für die Informatik im Unterricht der Sekundarstufe I, Informatik Spektrum, Band 9, Heft 2 (1986)
4. Gesellschaft für Informatik: Lehrerbildung im Bereich der Informatik, GI Empfehlung (1987). (Kurzfassung im Informatik Spektrum, Band 10, Heft 6, 1987; Langfassung: Beilage zu LOG IN 7, 1987, Heft 5/6)
5. Gesellschaft für Informatik: Fach Informatik in der Sekundarstufe II allgemeinbildender Schulen, Empfehlungen der GI, Informatik Spektrum, Band 16, Heft 6 (1993)
6. Puhlmann, H.: Grundsätze und Standards für die Informatik in der Schule: Bildungsstandards Informatik für die Sekundarstufe I; Empfehlungen der Gesellschaft für Informatik eV. LOG IN Verlag (2008)
7. Röhner, G., et al.: Bildungsstandards Informatik für die Sekundarstufe II. Beilage zu LOG IN, Heft 183/184 (2016)
8. The Committee on European Computing Education (CECE): Informatics education in Europe: are we all in the same boat? Technical report. ACM, New York (2017)
9. Bell, T., Andreae, P., Lambert, L.: Computer science in New Zealand high schools. In: Proceedings of the 12th Australasian Conference on Computing Education, pp. 15–22. Australian Computer Society, Brisbane (2010)
10. Duncan, C., Bell, T.: A pilot computer science and programming course for primary school students. In: Proceedings of the Workshop in Primary and Secondary Computing Education (WiPSCE 2015), pp. 39–48 (2015)
11. Brown, N.C.C., Kölling, M., Crick, T., Peyton Jones, S., Humphreys, S., Sentance, S.: Bringing computer science back into schools: lessons from the UK. In: Proceedings of the 44th ACM Technical Symposium on Computer Science Education (SIGCSE 2013), pp. 269–274. ACM, New York (2013). https://doi.org/10.1145/2445196.2445277
12. Brown, N.C.C., Sentance, S., Crick, T., Humphreys, S.: Restart: the resurgence of computer science in UK schools. ACM Trans. Comput. Educ. **14**(2), 1–22 (2014). https://doi.org/10.1145/2602484. Article 9

13. Hubwieser, P., Armoni, M., Giannakos, M.N., Mittermeir, R.T.: Perspectives and visions of computer science education in primary and secondary (K-12) schools. Trans. Comput. Educ. **14**(2), 1–9 (2014)
14. Knobelsdorf, M., et al.: Computer science education in North-Rhine Westphalia, Germany—a case study. ACM Trans. Comput. Educ. (TOCE) **15**(2), 1–22 (2015). Special Issue II on Computer Science Education in K-12 Schools
15. Hromkovič, J.: Einführung in die Programmierung mit LOGO. Springer, Wiesbaden (2014). https://doi.org/10.1007/978-3-658-04832-7
16. Serafini, G.: Programmierunterricht für Kinder und deren Lehrpersonen: Unterrichtsmaterialien, didaktische Herausforderungen und konkrete Erfahrungen. In: Gallenbacher, J. (ed.) Informatik allgemeinbildend begreifen, pp. 267–272. Gesellschaft für Informatik e.V, Bonn (2015)
17. Papert, S.: Mindstorms: Children, Computers, and Powerful Ideas. Basic Books Inc., New York (1980)
18. Hromkovič, J.: Homo informaticus. Why computer science fundamentals are an unavoidable part of human culture and how to teach them. Olympiads in Informatics **10**, 99–109 (2016). https://doi.org/10.15388/ioi.2016.07
19. Leonhardt, T., Schroeder, U.: go4IT!: Initiierung und nachhaltige Förderung von Interesse an MINT-Fächern bei Mädchen. Informatische Bildung in Theorie und Praxis, Beiträge zur INFOS **13**, 132–142 (2009)
20. go4IT! Website. https://schuelerlabor.informatik.rwth-aachen.de/go4it. Accessed 31 Jan 2018
21. InfoSphere- Schülerlabor Informatik der RWTH Aachen. https://schuelerlabor.informatik.rwth-aachen.de. Accessed 31 Jan 2018
22. Bergner, N., Holz, J., Schroeder, U.: InfoSphere: an extracurricular learning environment for computer science. In: Proceedings of the 7th Workshop in Primary and Secondary Computing Education (WiPSCE 2012), pp. 22–29. ACM, New York (2012)
23. Bergner, N.: Konzeption eines Informatik-Schülerlabors und Erforschung dessen Effekte auf das Bild der Informatik bei Kindern und Jugendlichen. Dissertation, RWTH Aachen University, No. RWTH-2015-06987. Fachgruppe Informatik (2016)
24. Open Roberta Website. https://www.open-roberta.org. Accessed 31 Jan 2018
25. Kümmel, A.: Ergebnisse der wissenschaftlichen Begleitforschung des Projekts "Roberta goes EU". Berichtszeitraum 15.1.2007–31.12.2007 (2008)
26. Leonhardt, T.: Etablierung eines begabungsfördernden Lernumfeldes für Mädchen im Bereich Informatik. Dissertation RWTH Aachen, No. RWTH-2015-00826. Fachgruppe Informatik (2015)
27. Parsons, T., Bales, R. F., Olds, J., Zelditch, M., Slater, J. R.: Family, socialization and interaction process (International library of sociology, 1998. Aufl.). Routledge, London (1998)
28. Campbell, A., Shirley, L., Caygill, L.: Sex-typed preferences in three domains: do two-year-olds need cognitive variables? Br. J. Psychol. **93**(2), 203–217 (2002)
29. Hyde, J.S., Else-Quest, N.: Half the Human Experience. The Psychology of Women, 8th edn. Wadsworth Publishing Company, Belmont (2013)
30. Mammes, I.: Förderung des Interesses an Technik. Eine Untersuchung zum Einfluss technischen Sachunterrichts auf die Verringerung von Geschlechterdifferenzen im technischen Interesse (Europäische Hochschulschriften Pädagogik, Bd. 835). Lang, Frankfurt am Main (2001)
31. Feng, J., Spence, I., Pratt, J.: Playing an action video game reduces gender differences in spatial cognition. Assoc. Psychol. Sci. **18**, 850–855 (2007)

32. Brauer, P.: Konzeption, Entwicklung und Analyse eines greifbaren Turtles in Hinblick auf die Steigerung der Computerselbstwirksamkeit von Schülerinnen und Schülern: Diplomarbeit am Lehr- und Forschungsgebiet Informatik 9, RWTH Aachen (2010)
33. Ziegler, A., Schirner, S., Schimke, D., Stoeger, H.: Systematische Mädchenförderung in MINT: Das Beispiel CyberMentor. In C. Quaiser-Pohl (eds.), Bildungsprozesse im MINT-Bereich. Interesse, Partizipation und Leistungen von Mädchen und Jungen, pp. 109–126. Waxmann, Münster (2010)
34. Kammer, T., Brauner, P., Leonhardt, T., Schroeder, U.: Simulating LEGO mindstorms robots to facilitate teaching computer programming to school students. In: Kloos, C.D., Gillet, D., Crespo García, R.M., Wild, F., Wolpers, M. (eds.) EC-TEL 2011. LNCS, vol. 6964, pp. 196–209. Springer, Heidelberg (2011). https://doi.org/10.1007/978-3-642-23985-4_16
35. Hidi, S., Renninger, K.A.: The four-phase model of interest development. Educ. Psychol. **41**, 111–127 (2006)
36. Krapp, A.: Pädagogische Psychologie. Ein Lehrbuch (Lehrbuch, 5. Aufl.). Beltz, Weinheim (2006)
37. Zwick, M.M., Renn, O.: Die Attraktivität von technischen und ingenieurwissenschaftlichen Fächern bei der Studien- und Berufswahl junger Frauen und Männer. Eine Präsentation der Akademie für Technikfolgenabschätzung in Baden-Württemberg. Akademie für Technikfolgenabschätzung in Baden-Württemberg, Stuttgart (2000)
38. Field, A.P.: Discovering statistics using SPSS. (and sex and drugs and rock 'n' roll) (Introducing statistical methods, 3. Aufl.), Los Angeles. SAGE Publications, Thousand Oaks (2009)
39. Renn, O.: Monitoring von Motivationskonzepten für den Techniknachwuchs. Herausgegeben von acatech - Deutsche Akademie der Technikwissenschaften. acatech BERICHTET UND EMPFIEHLT 5 (2011)
40. Hoffmann, L., Häußler, P., Lehrke, M.: Die Kieler Interessenstudie. IPN, Kiel (1998)
41. Heine, C., Egeln, J., Kerst, C., Müller, E., Park, S.-M. Bestimmungsgründe für die Wahl von ingenieur- und naturwissenschaftlichen Studiengängen. Ausgewählte Ergebnisse einer Schwerpunktstudie im Rahmen der Berichterstattung zur technologischen Leistungsfähigkeit Deutschlands, HIS (2006)