Volume 9

"Haus der kleinen Forscher" Foundation (Ed.)

N. Bergner, I. Chabay, H. Köster, J. Magenheim,
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Early Computer Science Education – Goals and Success Criteria for Pre-Primary and Primary Education

Scientific Studies on the Work of the
„Haus der kleinen Forscher" Foundation

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Early Computer Science Education – Goals and Success Criteria for Pre-Primary and Primary Education

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Early Computer Science Education – Goals and Success Criteria for Pre-Primary and Primary Education

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Kathrin Müller, Ralf Romeike, Ulrik Schroeder, Carsten Schulte

With a foreword by Ilan Chabay

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Contents

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Preface

Dear Readers,

Whether traffic lights, navigation devices in cars, parents‘ smartphones, tablets at the child-care centre or PCs in the classroom – children today grow up in a world that is significantly shaped by digital technology and is developing rapidly. Girls and boys want to explore and help shape it and have many questions: How does a robot work? What happens when I switch on the computer? And where do all the pictures and information come from?

The “Haus der kleinen Forscher” Foundation has been successfully developing and evaluating concepts and materials in the STEM field for exploration- and inquiry-based learning in early childhood education for many years. In 2018, the Foundation completed its groundwork in the areas of S-T-E-M with a volume on early computer science education, thereby laying the basis for its work on the topic of Computer Science. I am pleased that this English translation will allow us to provide our international readership with a slightly updated version of the volume.

By establishing the subject-specific basis for early computer science education, we have ventured into new territory, since there are still hardly any research approaches or educational concepts on this topic in the German-speaking world. At the same time, the importance of computer science and the competencies associated with it is steadily growing – something that became even clearer in the Coronavirus pandemic.

As far as children are concerned, the prevailing urge is a fascination with the world around them: they want to try things out, explore, participate and find out how things work and how they are interconnected. In doing so, they approach computers and other devices no differently than they do other intriguing things. How does all this information get into a little mobile phone? Why is my computer so fast? How do the traffic lights know when to indicate that cars or pedestrians are to stop or move?

Our task as an early education initiative is to enable educators to search for answers with the children.

For this reason, the “Haus der kleinen Forscher” Foundation focuses on the technological perspective of digital aspects in its educational offerings. There are now well-developed professional development concepts, educational materials and online offerings available for early childhood educators, primary school teachers and children that enable them to discover computer science – with and without computers.

The aim is not to increase the use of digital media but to understand the underlying concepts. Children can learn about algorithmic thinking in informatics systems hands on, thereby laying an important basis for reflective and competent use of these systems.

Pioneering work has been done in the field of early computer science education – I would like to express my sincere thanks to the authors of this volume for their great support and guidance in this exciting terrain. A responsible, open-minded and creative approach to computer science is important for our children and for the society of tomorrow.

I strongly believe that this volume and our educational offerings are able to contribute to ensuring that early computer science education is no longer uncharted territory in educational institutions throughout Germany, but a valuable part of good and successful early STEM Education for Sustainable Development.

Michael Fritz
Chairperson of the Executive Board of the “Haus der kleinen Forscher” Foundation

Foreword

Ilan Chabay

The first stanza of Bob Dylan's 1964 song ends with

"And you better start swimmin'
Or you'll sink like a stone
For the times they are a-changin'"

It has always been true that the times are changing, but what we humans face now are changes that challenge us in new and profound ways - ways for which many previously successful systems and approaches are no longer adequate. Thus, we need to continually find and learn new ways to swim in the fast-moving, turbulent stream we all inhabit on our shared planet Earth.

Finding and following culturally and contextually adaptive pathways to sustainable futures, including addressing climate change, is indeed a profound challenge. Successfully confronting a challenge of this magnitude and scope (e.g., as aspired to in the United Nations Sustainable Development Goals for 2030) requires not only that we use the best science and technology available. We must also learn to engage meaningfully in the collective decisions and actions to avoid, mitigate, or adapt to changing conditions in ways that are attuned to our diverse cultures and contexts.

Computer science and technology have already helped us immensely to understand the changes occurring on Earth with its limited resources and to slowly recognise the urgent need to change unsustainable patterns in society. At the same time, digital systems, vast data bases, and applications of rapidly increasing computational power (e.g., cell phones, navigation systems, and computers) have become nearly ubiquitous in society. But we have not yet equipped most young people in our societies to understand computer science and technologies, to use them most effectively for their purposes, and to play a role in the design of such systems and decisions whether to develop and deploy them or not. Nor have we made use of the powerful intellectual building blocks at the core of computer science to improve thinking strategies and skills that can be applied effectively not only in STEM (science, technology, engineering, and math) but in many aspects of our lives.

Why not? To incorporate computer science in STEM learning, we must overcome the widespread perception that computer science is a narrow domain of specialisation for "nerds" and "geeks" – neither relevant nor accessible to most adults and especially not to young children. This obstacle exists despite the nearly ubiquitous use, even by young children, of digital devices and computation in our daily lives. More to counter this point is in the work described in this volume of the "Haus der kleinen Forscher" Foundation, showing that young children are able to learn from aspects of computer science in developmentally appropriate ways. The misperception and failure to introduce the ideas and experiences is an obstacle to anyone, but it more frequently adversely affects girls and underserved and marginalized populations.

On the other hand, why introduce this domain of learning? Is it essential that these obstacles be overcome? What drives the "Haus der kleinen Forscher" Foundation and others to make the considerable effort to research the field and develop strategies and materials to introduce computer science to STEM learning for young children in and out of school?

There are several answers to these questions. At a meta level, offering developmentally appropriate experiences with computer science and digital systems engages children's curiosity and rewards it with positive, playful experiences. Such experiences and explorations build confidence and desire for learning about processes and content that affects the children's lives now and will do so in new ways in their future. This may form a strong platform not only for understanding and using digital media, devices, and computational power, but the interest and confidence to develop more fully their capacity to design and shape that future for their benefit and that of their society.

Learning with and about computer science and its manifestations from an early age through curiosity and play provides an excellent natural entrée to acquiring thinking skills of great value in every area of STEM (and indeed in all aspects of life!). The point is not only to learn about specific systems, processes, or devices, but to develop powerful learning strategies in an increasingly sophisticated way in order to approach new and more complex problems. This process can be started very simply by setting an objective and learning to dismantle the task into manageable steps leading to the objective. How do we get the penguin in the corner square on the grid to the delicious dinner in the centre and not bump into the seal or ice block on the way? We can try sequences of directional steps to reach the objective. This and other exercises can be done with an electronic robot, with paper and pencil on a grid, or children moving on a grid taped to the floor.

Even more complicated systems can be playfully explored in an elementary school classroom. For example, build a working model of the internet – no computer or electronic devices needed. Messages, each one sentence long, are writ-

ten on strips of paper. Then the messages are cut up into information packets that are sent across the room to their chosen destination. The packets travel by courier (children) from one way-station (where a child acts as router) to another to the final reception station where the packets are reassembled into a semblance of the original messages. The fun lies in the activity that engages the children (and teachers) in the formation of a model system with children as routers and carriers, designing and executing stepwise iterative instructions for the carriers of the packets of information, and laughing at and eventually troubleshooting the inevitably garbled messages that appear when the packets of pieces are reassembled into messages. This activity, which I designed for the US National Engineering Week in 2001 for the National Academy of Engineering and later used in elementary classrooms, is illustrative of the point made in this volume (p. 171):

> "[B]asic principles of communication on the Internet should be explored 'unplugged' using simple playful means, since a basic understanding of how the Internet works is an important part of computer science education. Suitable examples include role-plays on sending mail via routers,…".

These examples are very simple, but even so, they illustrate a fundamental facet of human thinking and learning, namely the use of models. Models may be tacit and procedural, as in learning from experience where to place your hands to catch the ball, or they may be highly complex computational models of natural or socio-ecological systems that inform our understanding of our challenges of achieving more sustainable futures. It is important to recognise that models are an essential part of how all humans process sensory data that we constantly receive. We need to make sense of inputs to make decisions in different situations that could be consequential – a glimpse of the on-coming truck as one start to cross the street – or on complex systems like the weather office estimating the likelihood of a flash flood occurring in a particular area. The critical issue is that our brains have a working memory bank that is unable to retain and process more than a few variables at any one time. Complex systems may have scores or even thousands of interacting components and variables in play. To begin to unpack and examine the options and consequences of potential decisions, models are essential tools. It is through decades of work by many scientists around the world using increasingly powerful computer models that we are making progress in many fields of science, as well as opening up new directions in music, visual arts, improved accessibility for the visual or auditorily impaired, and enriching or verifying historical records.

There are many types of analytical and computational models in use, but in most education settings from the primary through tertiary level, students are shown only the results of models rather than explicitly discussing the models that lead to the results. Learning computer science in early education, including the explicit processes of making and using different kinds of models, will help students develop and use models in their studies and better understand the influence of models in their livelihoods and private lives as citizens. Understanding the role of models and their value figures prominently not only in STEM but also for interpreting complex evidence needed for informed deliberation for decision-making on policy and practice in society. Learning the processes and content of computer science opens students to a wider range of possible livelihood choices as they develop. It also increases their understanding of the roles and impact that digital systems have in daily life.

Models are also the engines of the games that many children play on phones, tablets, and computers. As such, the games can be an appealing avenue into aspects of computer science. In a constructivist approach, children's interest in games provides a stimulus for deconstructing the operations and user interface of a game and then modifying the game or creating one's own game. The simple set of sequential instructions for moving a penguin around a space can become the starting point for a very elementary, "unplugged" game played on a physical two-dimensional grid, with one person "programming" the penguin's moves in coordinated time steps after the opponent decides where to place the hungry seal in order to try to intercept the penguin. That physical version can be developed into more complex and dynamic forms and be coded into a simple app as the students become more adept. This algorithmic process is at the core of animations and programming that students will encounter.

Depending on each child's interest and level, more sophisticated games with immersive environments, complicated logical branching structures, narrative flow, and tailored user interfaces become accessible for analysing, modifying, and emulating. If the basis for awareness of the computer modeling and processes operating beneath the surface of the game is introduced in early learning, electronic games become more valuable as environments for learning and creativity. As the children develop as learners, the activities can become more sophisticated and the connections to algorithms, coding, apps, models and games further developed.

The authors of the first expert report of this volume comment on the concern that media and games often are decoupled from learning by stating:

> "In our opinion, a special role of schools and possibly also child-care centres, could be to promote and point out further possibilities and types of interaction in addition to the predominant consumption activities. In addition, interactions could not only be experienced in isolation and individually, they could be experienced by parents and children together, so that the experiences can be verbalised and processed, as well as reflected on and classified in an age-appropriate way" (Bergner et al., p. 128).

The point made in the above quote about the experience as a group activity suggests circling back to emphasise the earlier concern about resistance or obstacles to introducing computer science in early learning venues. Engaging in designing or playing games that explicitly build on computer science processes are activities that in many cases can be done as group collaborations rather than only as individual efforts. This may help students, teachers, and parents see learning computer science less stereotypically as an asocial, strange, alienating activity and more as a socially connected one. Motivating collaborative learning opportunities in computer science can be done with many interesting project challenges at developmentally appropriate levels for young children. Developing the skills and pleasure for collaborative work from an early age, whether through computer science or other learning activities, is tremendously important. It is indispensable for finding interdisciplinary solutions for the many complex challenges we face.

In addition to finding time in the elementary classroom schedule and re-assigning priorities to include computer science, teachers who are adept and comfortable with the elementary content and processes of computer science are obviously needed. But a classroom with adequate materials and support is also a learning space for teachers willing to be co-learners with their students and colleagues. A wider introduction of computer science in early learning will require pre-service and in-service education of teachers and expert mentoring, but it will also be augmented by classroom experience. As parents and teachers, many of us have already learned from children who have already so rapidly acquired digital skills.

As stated on page 75 of this volume, "they should not only learn to deal specifically with a digital artefact, but also to confidently master general and transferable strategies for exploring an unknown system, while also thinking about its possibilities, limits and effects". It is not only a matter of understanding and thus being able to make better use of these artefacts and devices as children develop, but of becoming adept and comfortable in using what is learned in one domain and applying or adapting it to a problem in another domain.

Gaining domain knowledge and skills, as well as confidence in one's capacities learned in early childhood experience with computer science in STEM has great value beyond STEM. The same knowledge and sense of confidence is essential for making informed normative choices of safe and ethical use of technology but also for health and behavioural choices, which children will face even before becoming adults.

The thoughtful and evidence-based approach to computer science learning in STEM education of young children that is presented in this volume may have long term positive effects on the development of those children throughout their lives. One particular hope it raises for me is that the thinking skills, reliance on evidence-informed decision-making, and sense of personal agency with computer science and digital systems will provide a bulwark against the grip of baseless conspiracy theories and misinformation that threatens our societies.

The ninth volume in the series from the "Haus der kleinen Forscher" Foundation lays out a thorough and important examination of the rationale, educational framework, and materials for introducing computer science into the learning experiences of young children from pre-school through elementary school age. The needs of teachers of young children in and outside of school are addressed, as are the reasons that it remains difficult to engage some children, parents, and teachers in supporting the expanded offerings. The volume is not only a rich source of information and ideas for implementing computer science learning in STEM. It is also an inspiring call to action for parents and teachers alike to support the leap toward a future that helps all people to swim well in the turbulent stream that is our rapidly changing social-ecological system on Earth.

Prof. Dr Ilan Chabay
Research Institute for Sustainability Helmholtz Centre Potsdam

Introduction

“Haus der kleinen Forscher” Foundation

1 Overview of the "Haus der kleinen Forscher" Foundation

Since 2006, the non-profit "Haus der kleinen Forscher" (Little Scientists' House) Foundation has been committed to improving education for children between the ages of three and ten in the domains of science, technology, engineering/computer science, and mathematics (STEM). Together with its local network partners, the Foundation offers a continuing professional development programme throughout Germany that supports early childhood educators and primary school teachers in nurturing children's spirit of discovery and in facilitating their exploration and inquiry activities in a qualified way. The education initiative thus makes an important contribution to improving educational opportunities, fostering the next generation of professionals in the STEM fields, and professionalising pedagogical staff.

The educational initiative thus makes an important contribution in the following areas:

- qualification of early childhood educators
- quality development of institutions
- development of the children's personalities, abilities and interests
- promotion of the next generation of professionals in STEM educational fields

The main activities of the Foundation are:

- establishment and expansion of sustainable local networks with the participation of local stakeholders as well as counselling and support of the now more than 200 network partners,
- training multipliers (local trainers) who provide ongoing guidance for local early childhood educators, teachers and leaders,
- development and provision of professional development concepts and materials for early childhood educators, teachers and leaders,
- supporting the quality development of educational institutions based on "Haus der kleinen Forscher" certification, as well as
- the evaluation and scientific monitoring of the Foundation's activities.

Qualification initiative for educators

The “Haus der kleinen Forscher” Foundation is Germany’s largest early childhood education initiative in the domains of science, technology, engineering/computer science, and mathematics. It supports child-care centres, after-school care centres and primary schools in setting mathematical, computer science, scientific and/or technical priorities and establishing education for sustainable development (ESD), as well as creating a conducive development and learning environment for children. The Foundation’s educational approach builds on the children’s resources and emphasises joint exploration and inquiry in dialogue-based exchange (Stiftung Haus der kleinen Forscher, 2019a). Through its activities, the Foundation also promotes the implementation of the existing educational and framework curricula of the respective federal states in the areas of science, technology, engineering/computer science, mathematics and supports the anchoring of ESD in the educational areas.

The Foundation’s content-related offers include **professional development** for early childhood educators, teachers and leaders, as well as educational materials, an annual activity day and suggestions for cooperation:

- **Educational materials:** For practical implementation in educational institutions, the Foundation provides printed and online materials (available at: haus-der-kleinen-forscher.de) free of charge in its professional development courses, e.g., topic brochures, exploration and inquiry cards, didactic materials and film examples.
- **Website:** The website haus-der-kleinen-forscher.de provides information for all interested parties about the educational initiative: including the educational programme, contact with local training providers, inquiry ideas for children, scientific studies, brochures and picture cards for exploration and inquiry.
- **Campus:** On the online learning platform campus.haus-der-kleinen-forscher.de, early childhood educators, teachers and leaders can take part in open or moderated online courses and on-site training, or exchange ideas with each other in various forums. All of the Foundation’s online services are available free of charge
- **Blog:** The “Haus der kleinen Forscher” blog (blog.haus-der-kleinen-forscher.de) offers a forum for dialogue on good early STEM education for sustainable development. Here, the Foundation presents itself as a player in the national and international world of education and foundations while at the same

time providing a detailed look behind the scenes of the "Haus der kleinen Forscher".

- **Social media channels:** On Facebook, Twitter, Instagram and YouTube, the Foundation shows what good early STEM education can look like: *@kleineForscher* (on Instagram at *kleine_Forscher*). Here, current reports and studies are shared, videos of ideas and activities for exploration and inquiry are shown and information about the Foundation's latest educational offers is provided.

- **"Forscht mit!" magazine:** Every quarter, early childhood educators, teachers and leaders receive practical tips on exploration and inquiry at their institution, information on the Foundation's work and best practice reports from other institutions and networks.
- **"Tag der kleinen Forscher" (Little Scientists' Day):** On this interactive day, children all over Germany can explore current topics of inquiry. For this purpose, the Foundation provides educational institutions with material and calls on supporters from politics, business, science and society to join in.
- **Suggestions for cooperation:** Interested parents, sponsors and other educational partners support joint exploration and inquiry at the institutions.
- **Certification:** Committed institutions are certified as "Haus der kleinen Forscher" based on defined assessment criteria. All institutions that apply receive detailed feedback with suggestions for further developing joint exploration and inquiry with children.
- **Website for children:** At meine-forscherwelt.de, children of primary school age can access an interactive inquiry garden that encourages them to embark on independent journeys of discovery. Tips are available for educators on how to support learning.
- **Service portal integration:** At integration.haus-der-kleinen-forscher.de, early childhood educators, teachers and leaders receive support in the integration of refugee children at child-care centres, after-school care centres and primary schools through a variety of materials, practical ideas and a stimulating exchange of experiences.

Germany-wide networking

As a Germany-wide educational initiative, the “Haus der kleinen Forscher” thrives on the commitment of a wide range of local stakeholders – the local networks that act as permanent partners and training providers in the regions. There are currently 196 network partners, including municipalities and child-care sponsors, trade associations, science centres, museums, companies, foundations, associations etc. Since 2011, the initiative’s professional development programme has also been open to after-school care and all-day primary schools.

Approximately 86,000 early childhood educators and primary school teachers from around 35,000 child-care centres, after-school care centres and primary schools have already participated in the initiative’s professional development programme; among these are early childhood educators from around 28,000 child-care centres as well as educators and teachers from around 1,700 after-school care centres and around 5,300 (all-day) primary schools.

Across Germany, around 6,000 child-care centres, after-school care centres and primary schools are certified as “Haus der kleinen Forscher”, of which more than 5,400 are child-care centres. Since autumn 2013, after-school care centres and primary schools have also been able to obtain certification. More than 200 after-school care centres and over 300 primary schools have received the “Haus der kleinen Forscher” certificate since then (as of 21 October 2022).

The continuing professional development programme

The “Haus der kleinen Forscher” Foundation focuses on advanced qualification for educators in discovering and exploring mathematics, computer science, scientific and/or technical topics with children. Since 2018, advanced training courses have been offered with a focus on “education for sustainable development” (ESD). The aim is to provide continuous support for early childhood educators, teachers and leaders: Participation in advanced training courses on various topics successively expands participants’ methodological repertoire and deepens the understanding of the Foundation’s pedagogical approach. Alternating between face-to-face training and transfer phases, educators can try out what they have learned in practice and exchange ideas at the next training session.

In addition, the Foundation offers a constantly growing range of online courses which anyone interested can use individually, flexibly and free of charge to refresh or deepen their grasp of the subject matter. These include both open online courses, which can be attended independently at any time, and moderated online courses at fixed times. Here, participants work together on the content while the

moderator supports them. Web-based seminars (webinars) are scheduled for a specific time and include an interactive online talk. There are also topic-specific forums that allow professionals to reflect on their own practical experience together with other early childhood educators and primary school teachers.

To allow as many interested early childhood educators, teachers and leaders as possible to participate in the professional development programme, further qualification takes place via a multiplication model: The "Haus der kleinen Forscher" Foundation trains trainers at several locations in Germany. These trainers in turn offer professional development for educators in their local network (Stiftung Haus der kleinen Forscher, 2019b). By participating in the Foundation's face-to-face and online training courses, these trainers qualify to offer professional development courses for educators. They receive support in the form of detailed working materials for their task in adult education and also have the opportunity to gain personal feedback through the Foundation's training observation programme or in the form of video coaching. In addition, an online campus is available for the trainers to allow them to refresh and deepen their grasp of the subject matter. The digital learning platform offers a variety of online learning programmes, as well as content-related information and working documents for the individual training modules. For certain topics, there is the possibility to work independently on open e-learning modules, participate in tutor-led courses and use the online support courses for face-to-face professional dvelopment. In addition, trainers can get in touch with each other and exchange ideas in specific forums or open chats. The educational initiative offers different topics for trainers every year.

Since 2017, the Foundation has offered flexible entry to its educational programme for early childhood educators, teachers and leaders, as well as for trainers[1]. If the learning support staff see a need to expand their pedagogical competencies or would like to get an overview of the Foundation's pedagogical concept, they can start with the face-to-face professional development courses "Exploration and Inquiry with Water" or "Exploration and Inquiry with Air", in which the Foundation's pedagogical approach is explored in greater depth; or they can attend the seminar or online course "Basic Seminar – The Pedagogical Approach of the 'Haus der kleinen Forscher' Foundation". Likewise, early childhood educators,

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1 *By making the entry to the Foundation's educational programme more flexible, the Foundation assumes greater personal responsibility for its target groups. In accordance with the notion of the independent learner, which forms the basis of the Foundation's pedagogical concept, it relies on the fact that the early childhood educators, teachers, leaders and trainers can themselves recognise where they stand in terms of their interests and needs and which topic or format is the right entry point for them to the "Haus der kleinen Forscher" educational programme or which offering they wish to use for their further professional development. In order to support users in their professionalisation as learning facilitators in the best possible way, the Foundation offers targeted educational programmes and continuously develops these further in an impact-oriented and needs-based manner.*

teachers and leaders or the trainers can choose another module on mathematical, computer science, scientific or technical topics or on education for sustainable development as an introduction. The content is offered in different formats: on-site training, self-education formats (such as online courses or printed educational materials) and educational events. The "Haus der kleinen Forscher" certificate also supports quality development of the educational work at the institutions and makes the commitment to good early STEM education visible to the outside world. The Foundation is strongly oriented towards the needs, prior knowledge, previous experience and interests of its target groups.

The approach of providing support that is as individual and needs-oriented as possible – which the Foundation pursues both at the level of children and early childhood educators, teachers and leaders – is also implemented at the level of the trainers through the quality system for further training. The main elements of the system are the application and accreditation at the beginning of the trainer's activity, qualification phases designed according to needs and re-accreditation every two years. Based on the goal dimensions for multipliers of early STEM education, it systematises and expands the requirements for trainers and makes them explicit (Stiftung Haus der kleinen Forscher, 2019b).

The Foundation's offerings for early childhood educators, teachers and leaders are also developed based on sound goal dimensions relating to subject-specific criteria. They specify which goals are to be achieved in each case. Goal dimensions for children and early childhood educators and primary school teachers have been developed collaboratively with experts for the individual STEM disciplines, as well as for education for sustainable development and used as an orientation basis for the development of courses ("Haus der kleinen Forscher" Foundation, 2018; Stiftung Haus der kleinen Forscher, 2015, 2017a, 2018a, 2019).

The goal dimensions for early computer science education were developed and published in German for the first time in 2018 and are presented in this volume in English translation. At the beginning of the 2017/2018 academic year, the content of the Foundation's offers was expanded – to include the educational area of computer science education – with the workshop "Discovering computer science – with and without computers". In 2021, this was supplemented with the blended learning advanced training course "Computer science education in primary school teaching" (cf. chapter Conclusion and Outlook). All offers were developed based on the present expert report "Goal dimensions of computer science education at elementary and primary level".

In 2018, the Foundation also expanded its range of training courses, content and materials for education for sustainable development which is aimed not only at early childhood educators and primary school teachers, but also, for the first time, at child-care centre leaders. The latest training programme, "Rethinking

Consumption", offers educational staff and leaders at child-care centres the opportunity to learn more about consumption and sustainability at their institutions and address the topic with children. In 2019, the Foundation's offer was supplemented with the professional development course "STEM is everywhere", which for the first time addresses all STEM disciplines together and focuses on methods for learning support that apply to all STEM topics. In 2020, the number of new registrations on the online learning platform multiplied due to the Coronavirus pandemic. The Foundation reacted quickly, and within a very short time was able to offer additional online courses on topics such as "Co-constructive learning support", "Philosophising with children" and "Impulses in inquiry". Since 2021, early childhood educators, teachers and leaders have also been able to participate in online training courses via their local networks.

Scientific monitoring and quality development

All activities of the educational initiative are continuously monitored and evaluated scientifically. The "Haus der kleinen Forscher" Foundation maintains open exchange with science and professional practice and sees itself as a learning organisation.

A comprehensive range of measures serves to ensure and further develop the quality of the "Haus der kleinen Forscher" (see Figure 1). The Foundation's internal quality management covers all important activities and services with its own evaluation measures and comprehensive monitoring. For this purpose, the Foundation draws on a whole range of data sources (such as event-related surveys of network coordinators, trainers and early childhood educators, teachers and leaders); a combination of cross-sectional and longitudinal data enables a view of the current situation and also of important changes in recent years. In order to be able to react flexibly to the Foundation's need for insights, several surveys are conducted with different target groups at different points in time.

The longitudinal perspective plays an increasingly important role in the Foundation's internal evaluation and monitoring measures, also in order to meet the demand for stronger impact orientation. The Foundation provides important results of these measures in its regularly published monitoring report. For example, the 2016/2017 monitoring report uses an impact chain to describe how the education offered by the initiative contributes to improving early STEM education in Germany (Stiftung Haus der kleinen Forscher, 2017b). In the 2018/2019 monitoring report, the cross-sectional analyses are continued and methodically supplemented by results from the longitudinal study (Stiftung Haus der kleinen Forscher, 2020a). Further analyses of these data show that participation in a "Haus der kleinen Forscher" training course also has a longer-term effect on subject-didactic

knowledge, motivation and self-efficacy of the educators. The effects of participation in professional development are also related to the individual characteristics of the educators (e.g., initial level of competence and professional experience) as well as to the organisational framework conditions (e.g., STEM supervision ratio) (Stiftung Haus der kleinen Forscher, 2020a, 2022).

The content-related (further) development of new Foundation courses always takes place in a professionally sound manner and in collaboration with science; new Foundation courses are also developed and tested together and in exchange with working professionals. In cooperation with educators from child-care centres, after-school care centres and primary schools, each new training programme is tested in detail before the training concepts and materials are disseminated in the regional networks. In the process, the participating early childhood educators, teachers and leaders test the feasibility of initial practical ideas and provide feedback on the Foundation's support services. Educational concepts are revised and further developed based on this feedback.

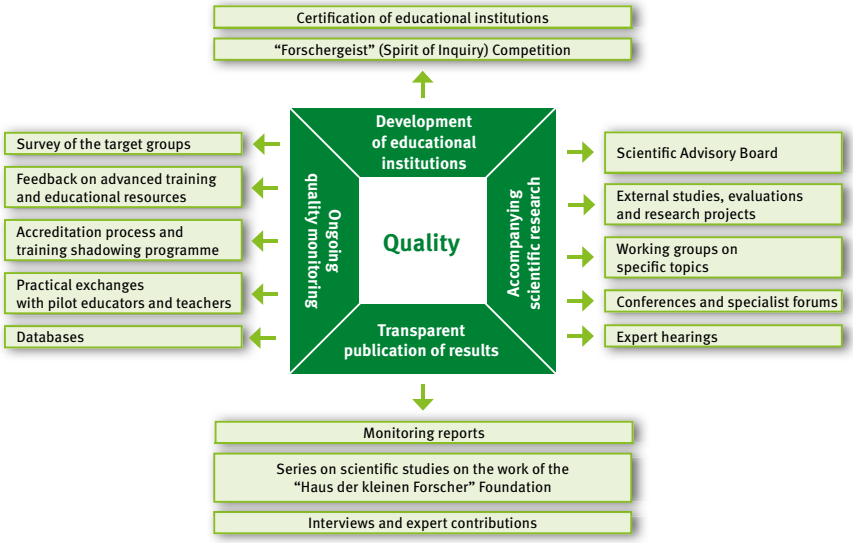


Figure 1. *Overview of measures to ensure and further develop the quality of the Foundation's services*

At the institutional level, "Haus der kleinen Forscher" certification is another important quality development tool (Stiftung Haus der kleinen Forscher, 2020b). The Foundation awards certificates according to a standardised procedure that was developed based on the "Deutsches Kindergarten Gütesiegel" (German kindergarten quality seal) and with the participation of a team of scientists (Yvonne Anders, Christa Preissing, Ursula Rabe-Kleberg, Jörg Ramseger and Wolfgang Tietze).

The reliability and validity of the certification procedure for child-care centres were confirmed in an external scientific study (Anders & Ballaschk, 2014). Certification as a "Haus der kleinen Forscher" is a free procedure for monitoring and enhancing pedagogical quality during the implementation of STEM educational content. By answering the questions in the certification questionnaire and receiving subsequent detailed feedback from the Foundation with practical suggestions and tips, child-care centres, after-school care centres and primary schools are supported in their quality development. Follow-up certification can take place every two years and enables the long-term anchoring and further development of educational quality at institutional level.

From 2012 to 2020, the "Deutsche Telekom" Foundation and the "Haus der kleinen Forscher" Foundation organised the nationwide "Forschergeist" child-care centre competition to honour the commitment of child-care professionals and the quality of institutions and to further motivate them to engage in early education work in the STEM field. In September 2019, the initiators launched the "Forschergeist" competition for the fifth time. Outstanding projects that inspire children for the world of science, technology, engineering/computer science, mathematics as well as education for sustainable development were awarded prizes in 2020. The award-winning projects were documented and published for each of the five competitions so as to serve as good examples to inspire other professionals for exploration and inquiry at child-care centres (Deutsche Telekom Stiftung & Stiftung Haus der kleinen Forscher, 2021)[2].

In addition to continuous monitoring for quality assurance and quality development, the Foundation's work is professionally substantiated and evaluated in research projects as part of long-term external accompanying research conducted with renowned partners. Two independent research groups investigated the impact of science education in early childhood from 2013 to 2017 (Stiftung Haus der kleinen Forscher, 2018b)[3]. The aim of the first research project "Early Steps into Science" (short: EASI Science, funded by the "Haus der kleinen Forscher" Foundation and the Federal Ministry of Education and Research) was to gain insights into the impact of early science education on the scientific competencies of educational staff and children at child-care centres. The results show that early childhood educators who have received further training in science have a higher level of subject knowledge and subject-didactic competence than a comparable group who have not attended such professional development courses. In addition, motivation for and interest in science education are greater among educators

2 *Documentation of the projects that won the "Forschergeist" competitions of 2012, 2014, 2016, 2018 and 2020 is available at forschergeist-wettbewerb.de.*

3 *Further information is available at www.haus-der-kleinen-forscher.de under the section "Scientific monitoring".*

who have received further training. Children also take more pleasure in learning, show greater interest in science and have more self-confidence in their own abilities if one of the focal points at their child-care centres is science (Steffensky et al., 2018). The second research project “Early Steps into Science and Literacy” (short: EASI Science-L, funded by the “Haus der kleinen Forscher” Foundation, “Baden-Württemberg” Foundation and “Siemens” Foundation) investigated the impact of language education and quality of interaction in the context of science educational programmes. The study showed that inquiry-based learning is well suited to language education. Educators who have attended professional development courses in science create more linguistically stimulating learning opportunities for children than educators without advanced training in this area. The children exhibit a higher level of linguistic competencies if their educators have previously participated in a combined training course on science and language offered by the “Haus der kleinen Forscher” Foundation. In addition, there are positive correlations between the science-related process quality designed by the educator and the children’s science skills (Rank et al., 2018).

With a view to the needs-based development of offers, from 2017 to 2019, the Foundation, together with the Federal Ministry of Education and Research, funded a study on the “Entwicklungsverläufe von pädagogischen Fach- und Lehrkräften in der frühen MINT-Bildung” (Early Childhood Educators’ and Primary School Teachers’ Professional Development; in short: EpFL MINT). The aim of the study was to investigate how self-perceived developments of early childhood educators and primary school teachers can be described in relation to professionalisation in the STEM field and whether different phases or formative events play a special role in the professional development of early childhood educators and primary school teachers. The results show that the number of training courses attended in the “Haus der kleinen Forscher” initiative is of central importance for professional development in early STEM education. The training courses also support educators in breaking down barriers to exploring STEM topics (Skorsetz, Öz, Schmidt & Kucharz, 2020).

Since 2020, the Foundation, together with the Federal Ministry of Education and Research, has been funding a study on the effects of the model programme “KiQ – gemeinsam für Kita-Qualität. Wenn Entdecken und Forschen zum Alltag werden“ (“Joining hands for quality in child-care centres. When exploration and inquiry become part of everyday life”). Through this child-care centre programme, the Foundation is looking at the institution as an overall system, adopting a continuing education approach that combines personal and organisational aspects and taking into account that the way an institution is managed and organised has an impact on the pedagogical work at that institution (Deutsches Jugendinstitut & Weiterbildungsinitiative Frühpädagogische Fachkräfte, 2014; Strehmel & Ulber,

2017). During the model phase (2020-2022), the "KiQ" programme will be evaluated by the Foundation and scientifically monitored by an external research group. The aim is to gain important insights into the success indicators for implementing exploration- and inquiry-based learning at child-care centres. Furthermore, recommendations are to be derived for future anchoring of the concept in the regular qualification offers of the Foundation and its eponymous professional development initiative "Haus der kleinen Forscher".

The Foundation draws on the findings of the studies to engage in systematic reflection on its existing educational offerings and the impact-oriented development of future professional development courses. The Foundation publishes the results of the scientific monitoring transparently in its publication series; all publications are also freely accessible on the website[4].

A Scientific Advisory Board supports the Foundation on research issues and in ensuring the Foundation's services are professionally sound. It is composed of independent academics from various disciplines and makes recommendations to the Executive Board and the Foundation Board. The members of the Board are high-profile experts from relevant disciplines and are appointed for three years respectively. From 2021 to 2023, the following members are as follows:

- Chairperson: Prof. Dr Mirjam Steffensky, University of Hamburg, Department of Educational Sciences
- Prof. Dr Yvonne Anders, University of Bamberg, Chair of Early Childhood Education and Upbringing
- Prof. Dr Nadine Bergner, Technische Universität Dresden, Didactics of Computer Science
- Prof. Dr Fabienne Becker-Stoll, State Institute for Early Childhood Research and Media Literacy (IFP), Munich
- Prof. Dr Wolfgang Böttcher, Münster University, Educational Science
- Prof. Dr Marcus Hasselhorn, German Institute for International Educational Research (DIPF), Frankfurt am Main, Department of Education and Development

4 *All results and publications in the area of scientific monitoring are available in PDF format at: www.haus-der-kleinen-forscher.de, under the heading "Scientific monitoring". All results of the external accompanying research are also published in this scientific publication series. An overview of the volumes published to date is available at www.haus-der-kleinen-forscher.de or at the end of this volume.*

- Prof. Dr Bernhard Kalicki, German Youth Institute (DJI), Munich, Department of Children and Childcare, and Evangelische Hochschule Dresden, Chair of Early Childhood Education
- Prof. Dr Olaf Köller, Leibniz Institute for Science and Mathematics Education (IPN), Kiel, and Kiel University
- Prof. Dr Nina Kolleck, Leipzig University, Political Education and Educational Systems
- Prof. Dr Armin Lude, Ludwigsburg University of Education, Department of Biology, focus on Education for Sustainable Development
- Prof. Dr Jörg Ramseger, Freie Universität Berlin, Chair of Primary Level Education
- Prof. Dr Hans-Günther Roßbach, University of Bamberg, Chair of Elementary and Family Education
- Prof. Pia S. Schober, University of Tübingen, Chair of Sociology with a focus on Micro-Sociology/Dr Ludovica Gambaro, University of Tübingen, Department of Education and Family
- Prof. Dr Christian Wiesmüller, University of Education Karlsruhe, Department of Physics and Technical Education, and Deutsche Gesellschaft für Technische Bildung (DGTB), Ansbach
- Prof. Dr Bernd Wollring, University of Kassel, Didactics of Mathematics

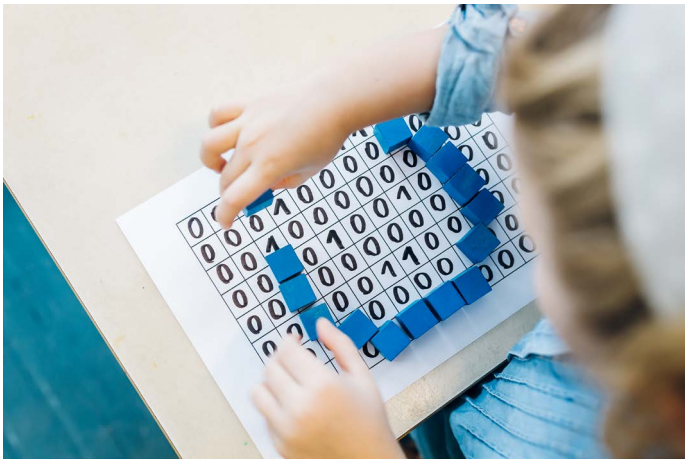
2 Relevance of Early Computer Science Education

We encounter computer science almost everywhere in our everyday lives, but we are often unaware of it. Whether we are waiting for the digitally controlled traffic light to finally turn green, operating our smartphone or switching on the fully automated washing machine: information technology is always with us and so it also plays an important role in the lives of children. According to a study commissioned by the German Institute for Trust and Safety on the Internet ("Deutsches Institut für Vertrauen und Sicherheit im Internet" (DIVSI)), "the increasing digitalisation of everyday life is already firmly anchored in family life for young children – as a topic and in their concrete actions" (DIVSI, 2015, p. 131). However, growing up in a digitally influenced environment does not automatically make children and adolescents competent users of digital technologies, as a study on computer and information-related skills among young people shows (Eickelmann, 2015). According to this study, almost 30 percent of young people in Germany do not have sufficient computer and IT skills for successful participation in society.

As part of the National IT Summit, which took place on 16 and 17 November 2016 in Saarbrücken, the German Mathematicians Association issued the following appeal: "Not the mere use of digital media, but the understanding of their fundamentals is what is required for an effective digital transformation. […] The aim should be to teach basic skills that enable learners to use digital innovations in a mature manner".[5] As such, computer science education is increasingly shifting into focus as a social task and should be an integral part of basic general education in the future. As a result, mastery of elementary methods and tools of computer science receives a similar status as writing, reading and arithmetic. All children should be given the opportunity to receive early education in this field. This means giving children leeway to ask questions about digital media and the informatics systems on which they are based and to seek answers through exploration and inquiry.

The "Haus der kleinen Forscher" addresses these challenges and aims to strengthen children's educational opportunities in a core area of digital education by providing further education and training for early childhood educators and teachers at child-care centres, after-school care centres and primary schools. While there are more and more initiatives on digital media use, the Foundation

5 *DMV (German Mathematical Society) press release on "Bildungsoffensive zur digitalen Wissensgesellschaft" (Education offensive for the digital knowledge society). Mitteilungen der Deutschen Mathematiker-Vereinigung (2017), 24(4), pp. 191-191. Retrieved March, 2022, from https://www.degruyter.com/document/doi/10.1515/dmvm-2016-0074/html*



focuses on computer science education at child-care centre and primary school age when developing early computer science education. There are no nationwide offers for computer science education for children aged 3-10 in Germany to date. While science, mathematics and technology education has been making its way into child-care centres for some years, there is a gap with regard to computer science education, which is constantly widening in the course of the digital transformation of society. The Foundation's goal in this area of education is to give children their first experience in the field of computer science in order to develop a basic understanding of informatics systems in the long term. Thus, in 2017, a professional development module on the topic of "computer science" was added to the Foundation's offer and expanded for primary school teaching in 2021. The aim is not to increase the use of digital media, but to understand the underlying concepts. The Foundation offers a series of courses for early childhood educators and primary school teachers to address the topic of computer science in their work with three- to ten-year-old children – also without using computers or tablets – and to implement this as has been commonly practised to date with everyday materials.

In order to meet the Foundation's high-quality standards, the content in the area of computer science education was also developed with professional and scientific support. Since 2015, the Foundation has therefore been in close contact with experts in the field of computer science education who critically accompany and advise on the development of the topic in specialist forums and expert meetings (see the following chapter).