

Promoting Talents for Computer Science

Sara Hinterplattner¹^a, Barbara Sabitzer¹^b, Heike Demarle-Meusel¹^c
and Hanspeter Mössenböck²^d

¹Department of STEM Education, Johannes Kepler University, Linz, Austria

²Institute for Systems Software, Johannes Kepler University, Linz, Austria

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Abstract: In the field of computer science there is a lack of qualified staff. Hence, more talents are needed, and universities try to attract students by launching different programs. The Johannes Kepler University Linz is very engaged in talent promotion and offers programs for all age groups from preschool up to higher education. The goal of these programs is to support gifted students throughout the grades in computer science as well as in their personal development. For this purpose, the students are challenged with creative interdisciplinary problem-based projects, all in connection with computer science. To achieve this goal all programs are based on the three pillars of honors education: creating community, enhancing academic competence and offering bounded freedom. In this paper we give an overview of all talent programs at the Johannes Kepler University Linz for different levels of education, some of them already proven and others in their first year respectively in their pilot phase with some unique selling points. We describe the three pillars of honors education applied in the activities as well as the planned evaluation.

1 INTRODUCTION

Talents promotion is essential in general, but especially in the field of computer science where a growing lack of qualified staff can be observed (Denning and Gordon, 2015), (Gershkoff, 2015), (Husing and Korte, 2010). Hence all activities and programs that attract students to computer science and help to find qualified staff in higher education are welcome. For this purpose universities have to make major efforts to recruit students. To achieve this aim, activities have to be designed with an out-of-the-box approach and should not only focus on university students. It is important to start as early as possible because in primary education the interests of children are developed and can therefore be more easily influenced (Mittermeir et al., 2010), (Köster et al., 2008). Long-term offers have the benefit that the programs can build on each other and the students are able to create a stronger bond with the university. It is crucial to design the contents tailored to the claims of the specific target

group, with the focus on promoting interest and increasing competences. As important as the content is the underlying didactic concept to impart knowledge. All the different programs presented below underlie one didactic concept, which is established in the field of talent promotion. This article gives an overview of the efforts of the Johannes Kepler University Linz to promote gifted students in the field of computer science.

2 RELATED WORK

Gifted students differ from other students in their high possession and use of untrained and spontaneously expressed natural abilities. Gagné defines this high possession to a degree that places the gifted students as the top 10 per cent of their age peers (Gagné, 2004). But the possession does not lead necessarily to excellence. Other factors like support and fostering are needed to unfold the potential of gifted students (Neubauer and Stern, 2007), (Ziegler, 2005). Therefore, talent development is needed to transform the natural outstanding abilities into outstanding knowledge and skills.

^a <https://orcid.org/0000-0002-9601-433X>

^b <https://orcid.org/0000-0002-1304-6863>

^c <https://orcid.org/0000-0002-4897-757X>

^d <https://orcid.org/0000-0001-7706-7308>

The benefits of talent development programs start in the early years of the students. Research shows that highly gifted students in primary school report several advantages of their gifted programs including increased learning and more interesting work (Moon et al., 2002). That leads us to the assumption that the talent development programs at the Johannes Kepler University Linz should start in primary school if not even in preschool.

The core of a talent development program is an enriched curriculum or training program. The reason for doing so is that gifted students need a different curriculum pace and difficulty level than average learners. These curricula should provide regular learning, the practice of activities and advanced learning activities (Berger, 1991), (Gagné, 2010). These include continuous and progressively challenging learning opportunities and environments in specific areas of talents. If there is an absence of these challenges in the educational environment it would lead to a negative impact on students' affect and cognition (Brighton et al., 2015), (Kulik and Kulik, 1992), (Rogers, 2007). This can cause boredom, underachievement and school dropout (Piske et al., 2016), (Maroldo, 1986), (Robinson, 1975), (Wasson, 1981). Besides, there will be disadvantages in the learning situation like slow learning pace in the classroom, low academic challenge and repetition (Adams-Byers et al., 2004).

To prevent these situations talent development programs need more depth, more connections and more applied learning, more space for creative unfolding, more attention to students' individual passion and interests. This leads us to the key components of honors pedagogy, the so-called 3 pillars of honors education: creating community, enhancing academic competence and offering freedom (Wolfensberger, 2012).

All children need to feel connected to others to develop in a good way (Ryan and Deci, 2000). Contrarily to the common opinion this applies also for gifted students who want to have normal social interaction with others (Coleman et al., 2015). Therefore, creating a community in the honors group sounds reasonable. This includes not only the community among the students, also a constructive and inspiring relationship between the teachers and the students is necessary (Wolfensberger, 2012).

Enhancing academic competence is of course part of a successful talent development program. This includes multi- and interdisciplinary thinking, multiple perspectives, scholarly teaching, academic depth, involvement in research, challenging learning tasks, difficulty and acceleration. (Wolfensberger, 2012)

The opportunity to work independently is important for gifted students (Rogers, 2007). But there has to be a framework so that they don't get lost. Hence, offering bounded freedom for the students is necessary for a successful program. This includes flexibility, allowing for self-regulation, openness, innovative teaching, experimentation, fun, professionalism, novice relationship and challenge.

All these aspects were considered in the talent development programs at the Johannes Kepler University Linz.

3 PROMOTING TALENTS FOR COMPUTER SCIENCE

3.1 CS Talents Promotion in Upper Austria

With the aim of implementing a sustainable talents promotion in the field of computer science across all ages a very fruitful cooperation has been initiated in Upper Austria in 2017 between the association *Talente Oberösterreich* (Talents Upper Austria), shortly *Talente OÖ*, and the new *COOL Lab* at the Johannes Kepler University Linz. *Talente OÖ* is an association that aims at promoting highly gifted children and adolescents in different fields, mainly in the STEM subjects (*Talente Oberösterreich*, 2019). The *COOL Lab* is a teaching-learning lab that aims at fostering computational thinking and digital literacy for different target groups in the educational field as well as attracting the participants for computer science (Sabitzer et al., 2018).

The programs, courses, workshops and clubs at the Johannes Kepler University Linz reach gifted and interested children and adolescents beginning at the age of four years up to students of bachelor and master level. The main aims of the *COOL Lab* are (1) rising interest for computer science and STEM in children and adolescents of all ages, (2) bringing computational thinking and digital literacy to a broad audience, as well as (3) attracting highly gifted children to computer science and motivating them for further studies and/or work in this field. In this paper we focus on the latter one and describe current programs for high-flyers of all ages offered by the Johannes Kepler University Linz, especially by the *COOL Lab*. Some of them are developed and accomplished together with *Talente OÖ*, some were already developed before and only implemented in this cooperation. The following section gives an overview of the programs and their contents.

Table 1: Programs for Gifted Students - Overview

Program	PreS	PE	SE1	SE2	HE
Informatics Lab	x	x	x	x	
Mini Talents Club		x			
Mini:Mints	x	x			
Talents Club			x		
Cyber Tutoring			x	x	x
Tutor training		(x)	x	x	x
COOL Internships				x	x
Young Computer Scientists				x	
Head Start				x	
JKU Honors					x
Student researcher		x	x	x	x

PreS = Preschool, PE = Primary Education, SE1 = Lower Secondary Education, SE2 = Higher Secondary Education, HE = Higher Education

3.2 Best Practice Programs of the JKU COOL Lab

In order to give an overview of the talent promotion programs at the Johannes Kepler University Linz they are listed in Table 1 including the corresponding age groups. Aims and contents of the different programs are described in the following paragraphs.

3.2.1 Preschool and Primary School

As already mentioned, for rising interest in children it is important to start as early as possible. For children in kindergarten, preschool and primary school we offer special programs that follow the concept of *Informatics - A Child's Play?!*, a project (Sabitzer et al., 2014) that in part builds on *Computer Science Unplugged* (Bell et al., 2009) and *Informatik er-Leben* (Experiencing Informatics) (Bischof and Sabitzer, 2011): Computer science concepts are presented in a playful way by using games, animations and hands-on materials and activities to train computational thinking.

The *Informatics Lab* (Pasterk et al., 2016) is the chronologically oldest program, which has already been developed in 2013 by one of the authors at her previous university. (xxx, 2016) Now it is part of the *COOL Lab* and can be visited every two weeks by everyone beginning at the age of four years. For highly gifted children it is further the basis for other *COOL Lab* activities and programs like the *COOL Talents Club* and the *Mini Talents Club* as well as the new tutor training. In this laboratory every visitor can discover different computer science concepts and can practice basic computational thinking through activities like the bee-dance or treasure hunt.

The *Mini Talents Club* for highly gifted children from seven to ten years is a cooperation between the Johannes Kepler University Linz and Talente OÖ. It takes place every two weeks in the *COOL Lab* and builds on at least one visit to the Informatics Lab, but goes further and integrates topics of all STEM subjects. The idea is to use computer science concepts and techniques in order to learn and elaborate STEM contents, e.g. visualizing the ingredients and procedure of a chemical experiment by using class and activity diagrams as a sort of advance organizers. Depending on age, competences and interests of the children, they invent and develop new and innovative products, e.g. a LED monster.

At the moment there are 21 children and two advisors, who meet in the *COOL Lab* every second week to discuss different topics. First, the young researchers choose several topics out of a pool covering all natural science (STEM) subjects taught at school. These topics are introduced by lecturers, which are teachers of the respective subjects. Furthermore, students of the Johannes Kepler University Linz assist the children in understanding the assignments.

The new program *Mini:MINTs* starts in summer 2019 in cooperation with *kidsversity*, the kindergarten for the children of the staff and students of the Johannes Kepler University Linz. In a first step, the kindergarten teachers participate in the *Informatics Lab* and discover concepts appropriate for "their" children, like sorting with Lego bricks, algorithms in natural language, coding with Ozobots, modeling with pictures as well as logic and simple truth tables filled in with green checks and red crosses (instead of 1 and 0). Afterwards, *COOL Lab* trainers give workshops for the children, where the kindergarten teachers already give input and/or support the children in

their tasks. After this phase of "learning by doing" the teachers should be ready to continue working without further support and practicing computational thinking.

3.2.2 Secondary School

Most of the programs at the Johannes Kepler University Linz are offered for students of secondary education (grades 5-13) with a strong focus on lower secondary schools (grades 5-8), where basic digital education including computational thinking is obligatory in Austria since 2018. The *COOL Talents Club* is a cross-curricular learning lab for highly gifted students from grade five to eight, who are interested in STEM topics. Like the Mini Talents Club the *COOL Talents Club* has been developed by the *COOL Lab* team and is offered every two weeks in cooperation with Talente OÖ. The aim of this course is fostering talents in the field of STEM with a strong focus on IT and computer science. The children work on different projects around topics of different fields and use technologies as well as computer science concepts like modeling in order to solve tasks and develop innovative products. The topic of the first Talents Club was "wearable technology", the current is under the motto "useful and intelligent objects".

The program *Cyber Tutoring* is proposed by Talente OÖ and is especially aimed at girls between 13 and 16 years, who are supervised over two years by women in higher positions in the field of STEM. All in all, there are 13 girls in the program that started in autumn 2018 and six of them are supervised by the *COOL Lab* team. The girls are involved in research projects of the department, act after an introduction as peer tutors in the *Informatics Lab*, develop their own projects and products, as well as participate in the new tutor training for basic digital education.

The *Tutor Training* starts in March 2019 and is open for gifted students from 12 years on. They get an introduction into topics of computer science as well as pedagogy in order to be able to teach basic computational thinking to children and teachers of their own schools. The training is divided into three input units at the university and two practice phases. During this time the prospective tutors already give workshops in their schools, supported online or by phone by *COOL Lab* trainers.

The *COOL Internships* are dedicated to the work in the *COOL Lab*, which can regard different subjects and (research) fields depending mostly on the interests and competences of the students. The internships are offered for students of higher secondary schools (beginning at the age of 15). These internships include the work in interdisciplinary (research) projects

together with *COOL Lab* trainers and scientists, conducting individual projects e.g. for the A-level exam in a vocational high school, activities with children in the *Informatics Lab* or the Talent Clubs described above or even writing (pre-)scientific papers or theses together with or under supervision of scientists. The students can take part in these internships for a total of 120 hours in 4 weeks during their summer holidays or even work part-time during the school year when their schedule allows it.

3.3 Best Practice in Computer Science

3.3.1 Young Computer Scientists

The *Young Computer Scientists* program is part of the *Young Scientists* initiative that was launched in 2012 to get a larger number of gifted high-school students interested in STEM studies (Johannes Kepler University Linz, 2019b). *Young Scientists* is a cooperation between the Johannes Kepler University Linz, Talente OÖ, and the Upper Austrian Chamber of Commerce. More than 100 students participate in this program each year, about 20 of them in the Computer Science branch.

The *Young Computer Scientists* program consists of six hands-on workshops on various topics of Computer Science, as well as an optional summer internship at renowned local IT companies or at the *COOL Lab*. The topics of the workshops range from game programming to internet security, deep learning, simulation, computer graphics, and signal processing.

3.3.2 HeadStart@Informatics

Recently, the Department of Computer Science at the Johannes Kepler University Linz has implemented various measures to attract young people to study Computer Science. These measures have more than doubled the number of new students in the last 5 years.

One of the latest measures at the Johannes Kepler University Linz is a program called *HeadStart@Informatics*, which allows gifted students in their final two years of higher secondary schools to attend selected courses of the Computer Science Bachelor's program (Johannes Kepler University Linz, 2019a). They are then enrolled as extraordinary students and are entitled to attend one introductory course per semester. The following courses can be attended:

- Introduction to Digital Circuits
- Introduction to Programming
- Introduction to Databases

These are the regular courses that are also taken by full-time students so that the pupils get a good understanding of what it means to study Computer Science. The exams are later credited when the pupils start their proper studies. Thus, they gain a head start over students starting from scratch.

During this time, the high school students are exempted from tuition fees, which is made possible by a cooperation with the Federal Ministry of Education and the ÖZBF (Austrian Research and Support Centre for the Gifted and Talented).

HeadStart@Informatics offers a number of advantages: Students get to know the basics of computer science at an academic level, which is usually well beyond what they learn in school. For motivated students this is an excellent opportunity to quench their thirst for knowledge and to experience what Computer Science is all about. They can thus better decide whether Computer Science is the right thing for them. If they decide to continue with Computer Science, their regular start of studies will be much smoother than without this experience, thus reducing the dropout rate. Last but not least, it is motivating to be a university student already at the age of 17.

For the university, the advantage of *HeadStart@Informatics* is that more young people are attracted to studying Computer Science, which increases the number of students in this highly sought-after field. Another advantage is that the Johannes Kepler University Linz is thus curbing the migration of young people to other places of study, a problem that many regional universities have compared to larger universities. Those who study elsewhere usually do not return to their home area when they reach out for a job later, which has a negative impact on the labor force in the region.

3.4 JKU Honors Program

The *JKU Honors Program* is designed for gifted students at the Johannes Kepler University Linz who have the motivation and the ability to do more than a regular program can offer. This should include by definition academic challenges but also aspects to broaden their personal development and their interdisciplinary thinking (Clark and Zubizarreta, 2008).

The participants receive individual support and soft skills training, gain experience and competencies for scientific work and research, develop their creativity, carry out individual projects and deepen their areas of expertise and complementary subject areas to broaden their horizons. They have the opportunity to interact with other participants and get in touch with top executives at the Johannes Kepler University Linz

who will talk about their research, their career and their person.

Besides their own scientific training the students also support younger gifted students with their projects. One example of this tutoring is the *Children's Congress* at the Johannes Kepler University Linz. In this annual event participating children can slip into the role of researchers and present the results of their projects accomplished by the Honors students. The projects stand out because of their creative ways of implementing cross-curricular computational thinking. Besides their academic competence, the Honors students have to support the children by showing them how to get the best out of their giftedness. This collaboration is described as very inspiring and motivating from both sides.

With this program, the Johannes Kepler University Linz makes a major contribution to the promotion of talent at universities and supports particularly gifted students in their development.

Student Researchers can do research projects or participate in projects in all levels of education, even primary schools. Together with the *COOL Lab* team and scientists - and in the case of the *Children's Congress* (xxx, 2018) also with their teachers and teacher students - children and adolescents of all the talent programs of the Johannes Kepler University Linz or partner schools pose research questions, try to solve them, report on their projects and present them as well as the developed products and gained results at an appropriate event.

4 THE 3 PILLARS OF HONORS EDUCATION

In the development of the programs the 3 pillars of honors education where taken into account.

4.1 Creating Community

In the programs, creating a community is an important issue. The students often work in groups and are in active exchange with their teachers or mentors. For communication common platforms are used where new ideas, projects or problems can be discussed. The first attempts have started to interconnect the individual programs. The Honors students work in several projects with younger gifted students and support them. Also in the tutor programs younger gifted students are encouraged by the older gifted students.

In order to make the talents program visible to other students, there are public events at the end of all programs. There the results of the projects, the

student's experiences and their gained knowledge are presented to parents and peers. Outstanding achievements will be rewarded in the course of these events.

4.2 Enhancing Academic Competence

The broadening of the own academic competence is of course a reason why the gifted students want to participate in the programs. In every program the questions are raised "What do we learn in this program?" or "What do we get out of this program?". And the answers to these questions include own research and interdisciplinarity. Often students are focused on a specific subject, because they are used to it from school. But in the gifted programs at the Johannes Kepler University Linz it is not enough to be good in one domain, the creativity and the out-of-the-box thinking is fostered. The students participate in projects on different and interdisciplinary subjects to ensure a higher competence in important subjects or dimensions of being a gifted students with the ability to change the profession that they are in. Topics like innovation and entrepreneurship, networking or project management prepare the students for their further life. Combined with skills in computer science like programming or computational thinking, the students get a solid and important grounding for projects even in disciplines other than computer science.

The own research is a big part of every project. The students are challenged with real-world problems in STEM fields and demanded a variety of approaches. Often students have to start with a lot of research, doing many experiments and finally create their own products that are presented at the final events (Hinterplattner and Sabitzer, 2018).

4.3 Offering Freedom

In every program the students get their freedom to work on their interests in a specific framework. This approach is called bounded freedom. As mentioned before, this should be part of every gifted program, because the gifted students want to develop their own ideas. The teachers or mentors will often define tasks or highlight problems in existing solutions, making it the students' task to improve or implement solutions to solve these challenges. In every project the gifted students bring their own ideas and experiences in and work together in groups and develop a learning space, where collaboration and peer sparing and evaluation becomes a center stone for the student's own work. This allows the students a work process with a lot more inspiration, and a faster feedback on ideas and possibilities for their personal projects. This also

creates a strong sense of community, giving the students a safety net, allowing them to reach for higher goals with their projects.

Working on these individual projects where there is no fixed solution or at least no fixed way to get to a solution gives a student a lot of room to try out skills and make precious experiences.

5 EVALUATION

It is crucial to evaluate the offers set by the Johannes Kepler University Linz to foster gifted students. As described above, most of the offers are very recent. That gave us the opportunity to coordinate the design of the target-group-specific offers. Every effort set pursues three main goals: (1) to promote talents (2) to increase interest in computer science and (3) to foster youth development at the Johannes Kepler University Linz. Thus the evaluation concept is balanced with these three evaluation goals.

Promoting talents: One focus lies on the three pillars of honors education: creating community, enhancing academic competence and offering freedom. For this, the structure of the offers is matched up with these three pillars. The task of the evaluation will concentrate on the quality of implementation. A second focus is on the interdisciplinary work and projects on interdisciplinary themes. All programs force problem-based learning and interdisciplinary problem-solving to foster relevant 21st century skills. To evaluate these aims, the concepts and set framework conditions will be reviewed by experts from the university.

Increasing interest in computer science: A way to increase interest in one subject is to create the possibility to get in touch with the topic. The contents of all offers are entangled with computational thinking, with the aims to adjust the image of computer science within the target groups and to increase the knowledge of it. Some offers of the university will not only be reserved for gifted students, but for all interested students, with the aim of fostering interest in computer science. To evaluate this we will analyse the products developed by the students and conduct a questionnaire survey.

Fostering youth development: A quantitative analysis will be set to answer the question, if the offers bind students to the university and whether the offer is accepted or not. In the second case, results of the formative evaluation will be important to intervene at an early stage.

Experiences: Having an overview of the current talents promotion activities at the Johannes Kepler

University Linz respectively analyzing the status-quo including the three pillars of education, is the basis for the current work at the Johannes Kepler University Linz: the development of an overall concept of a seamless talents promotion in computer science across all age groups and educational levels. The underlying didactic framework is COOL Informatics, the flexible and "brain-based" teaching approach of the COOL Lab of the Johannes Kepler University Linz. With this concept and its 4 principles - *discovery*, *cooperation*, *individuality* and *activity* - we have already gained some positive experiences in bachelor programming courses: we could reduce the drop-out rate, close the usual gender-gap concerning the performance, as well as increase the average learning outcomes (Sabitzer and Pasterk, 2014). We are still at an early stage in the development of the overall concept, where we cannot present empirical results yet. However, the positive feedback of the participating students as well as their parents gained so far shows that we are on the right way.

6 CONCLUSION AND OUTLOOK

Talents promotion is essential especially in the field of computer science, where a growing lack of qualified staff can be observed. There are already several activities for gifted students at the Johannes Kepler University Linz, in part developed and offered in cooperation with Talente OÖ. They allow us to reach children and adolescents of all levels of education from kindergarten up to university level. With this varied and seamless talents promotion in computer science we want to increase interest and attract more students, especially females, for a further career in this field. We have already got some positive feedback from students and parents, which shows that we are on the right way. Currently, we are developing an overall concept for a seamless talents promotion in computer science, based on the three pillars of honors education as well as on a common didactic framework: COOL Informatics. The talents promotion at the Johannes Kepler University Linz is already good and appreciated. With the further development and application of the planned overall concept, it may become a flagship for talents promotion in computer science for other regions, too.

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