COOL Informatics: A New Approach To Computer Science and Cross-curricular Learning

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Abstract
Children grow up as "digital natives", but nevertheless, they don't know the concepts behind technology and they don't choose technical careers because of different reasons. In many countries there is a lack of experts, particularly females, in technology and computer science. Reasons for this situation may be missing interest or the belief that technology is (too) difficult and complex. Hence, it is necessary to arouse the interest in children and to reduce or avoid fears of technology. These are the main aims of COOL Informatics, a teaching approach developed at our university including the principles *discovery, cooperation, individuality* and *activity*. It was introduced on different levels of education and shows that informatics is "cool" in the sense of motivating, fun and "easy" by exploring its core concepts in a playful and illustrative way. It is partially based on approaches like CS unplugged, but it goes further: It uses informatics concepts like algorithms or modeling to support learning in other subjects from elementary education up to university level. The paper gives some examples for different school levels and reports on experiences of students and teachers as well as on empirical results of some pilot projects. Summarizing them, the following core messages can be made: we could enhance the understanding of complex informatics contents and increase the interest in computer science.

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Introduction

Today's society has changed. Hence, teaching and learning should change, too. This is all the more the case in Computer Science Education, Informatics and Technology. Today's children are sometimes called digital natives because they are growing up with computers and smartphones. But, growing up with technology and using it every day does not imply responsible and correct use. It doesn't imply either that today's children and adolescents learn more about the concepts behind technology, neither in informal nor in formal learning settings. Despite growing up with technology, only a few adolescents choose a technical career like computer science. Hence, increasing interest in technology and teaching it in a way that motivates students and supports their understanding and learning, is of central importance for meeting the current lack of qualified technical staff.

In Austrian schools computer science education is not organized uniformly. With the exception of some schools with a special IT-orientation, computer science only starts in the 9th grade, at the age of 14. This may be late for arousing interest in technology. Consequently, a central question of this thesis is: What can schools and teachers do to promote interest and enthusiasm for technology in children? Our personal answer is: We should show that informatics is "cool" by using it as a tool and integrating informatics concepts in all subjects and on all levels. This is why we introduced the COOL Informatics approach where COOL refers to the following three meanings:

1. "Cool" as motivating, interesting, fun and effective.
2. COOL as COoperative Open Learning refers to an Austrian teaching model based on the Dalton-Plan (Greimel-Fuhrmann, 2006; COOL Impulszentrum) that offers thematic, methodic and institutional openness as well as cooperation on different levels and between different subjects.
3. COOL as COmputer-supported Open learning refers to all forms of technology-supported learning, like CSCL (Computer-supported Collaborative Learning), E-Learning or Mobile Learning as well as eCOOL, the E-Learning variant of the COOL teaching model.

A playful, fun and "cool" approach to technology and informatics that is implemented during early childhood could do more than raise interest and lay a good foundation for logical and computational thinking. It may also mitigate fears or gender differences regarding interests and performance in technical subjects. An interdisciplinary and cross-curricular use of computer science concepts (NOT only computers) does not only offer more possibilities of practice for more sustainable learning. Besides showing a wide range of application areas of computer science, it can also foster creativity as well as cross-linked thinking and it can support teaching and learning in other subjects.

"COOL Informatics" is not simply a combination of these fields, but it goes further. On the one hand it extends the aspect of computer-supported learning to "computer science-supported" by implementing core concepts of informatics in other subjects (e.g. modeling or algorithmization in foreign languages). On the other hand, it offers a new framework for other subject specific didactics and shows how to put in practice what neurodidactics proposes for effective teaching and learning.

Corresponding to the different meanings, the theoretical background of the "COOL Informatics" approach includes numerous teaching concepts and methods as well as a wide range of related work. It would go beyond the scope of this paper to consider all these fields in depth. As a result, only the most relevant literature is cited in the context of each realm.

Concerning the first meaning of "cool", it can be seen from a teacher's or a student's perspective. "Cool" from a teacher's view means effective as summarized by Erlauer (2003):

> "Effective teachers are using multimodal strategies such as hands-on discovery, discussion, experimentation, high-level thinking and problem solving, activities involving all multiple intelligences, offering choices, authentic learning and assessment, tying learning to emotions, and collaborative learning for teaching and assessment." (Erlauer, 2003, p. 131)

This includes concepts and methods applied for centuries by good educators and teachers as the following statements of famous people show:

(1) "Tell me, and I will forget. Show me, and I may remember. Involve me, and I will understand." Confucius (551 – 479 B.C.)
(2) "You cannot teach anybody anything. You can only help them discover it within themselves." Galileo Galilei (1564 – 1642)
(3) "Help me to do it myself. The teacher thus becomes a director of the children's own spontaneous work. S/he is silent and passive." Maria Montessori (1870 – 1952)

These quotes (Brainyquote, 2011-2014) are part of progressive pedagogy and/or constructivist learning theories and most of them already anticipate the findings of neurodidactics (Sabitzer, 2011). They refer to teaching methods proved as effective in different empirical studies and summarized in a meta-study (Hattie, 2009). Hattie ranks the following methods as effective: *learning by doing* or *active learning*, *questioning*, *cooperative learning*, *small group learning*, *peer tutoring* and the use of *worked examples* (Hattie, 2009; Renkl & Atkinson, 2002).

From a student's view the adjective "cool" means fun, interesting and/or useful. This is one aim of neurodidactics and can be satisfied by using games in the classroom, not only by playing but also by designing them (Claypool, 2005). This is the context of research in game-based learning, educational games, serious games (Conolly et al., 2012) or learning by simulation (Bollin, 2012). Similar animation is offered in CS Unplugged (Bell et al., 2009) or Informatik erLeben (Mittermeir, Bischof & Hodnigg, 2010). These approaches teach informatics concepts in primary schools without using computers. The children slip into the role of hardware components or data and animate them. This is a very effective and sustainable form of learning as demonstrated in a variety of studies (Bell, Lambert & Marghitu, 2012; Bischof, 2011).

The second meaning of "COOL" (COoperative Open Learning) refers to an Austrian teaching model that has been developed by teachers in a vocational high school, in cooperation with a school in Denmark. It is based on the Dalton Plan of Helen Parkhurst and combines two approaches, *open learning* as well as c*ooperative* or *collaborative learning*. Up to now only a little research has been done concerning

COOL, but the few results confirm its effectiveness, e.g. (Greimel-Fuhrmann, 2006). A qualitative study, accomplished in a vocational school, shows a wide acceptance among teachers and students (Windbichler, Haslauer & Marschnig 2012).

Scientific research that is relevant in the context of COOL focuses only on one of its aspects. Many studies prove the efficiency of cooperative learning as already mentioned above (Hattie, 2009; Roseth, Johnson & Johnson, 2008, Porter et al., 2013). Regarding open learning, the results are fragmentary and not uniform. This is due to its varying definitions according to the different aspects and grades of openness (Peschel, 2006; Bohl & Kucharz, 2010).

"COOL" as Computer-supported Open Learning refers to all forms of technology use for learning and teaching, which includes E-Learning, Computer-supported Collaborative Learning (CSCL), Technology Enhanced Learning (TEL), Mobile Learning, One-to-One TEL as well as Web 2.0 or Learning 2.0 etc. Literature in this field is numerous for different subjects, especially for language learning. Contemporary aspects of computer-assisted language learning (CALL) and different CALL learning environments are described in (Thomas, Reinders & Warschauer, 2013). Their "Project Tomorrow" summarizes results of empirical studies in the USA concerning the benefits of online learning, personal access to mobile devices, needed ICT-skills, the role of parents and school infrastructure.
Mobile Learning, too, is more and more studied and regards different aspects like accessibility (Speak up, 2011), acceptance (Demouy, Eardley & Kukulska-Hulme, 2013), efficacy, mainly because of increased motivation (Sandberg, Maris & de Geus, 2011), and design (Wu et al., 2012).

COOL INFORMATICS

The COOL Informatics Approach

The teaching approach "COOL Informatics" is based on neurodidactical principles and contains four main principles. The following table (Sabitzer, 2014) shows the related teaching and learning methods as well as their neurodidactical basis.

"COOL Informatics" – Overview		
Principle	**Teaching and learning methods**	**Neurodidactical basis**
1. Discovery	Solution-based learning (worked examples) Step-by-step instructions + tasks Observational learning Video tutorials Hands-on, Minds-on Learning with all senses	Pattern recognition Mirror neurons Individual learning rhythm modality / multimedia effect
2. Cooperation	Team and group work Peer tutoring and -teaching Pair programming Cross-curricular learning Project-based learning	"A joy (=knowledge) shared is a joy (=knowledge) doubled." Recall = re-storage in long-term memory Integrating individual needs, talents and competences as well as practical relevance

3. Individuality	Competence-based learning Questioning Self-organized learning with compulsory and optional tasks	Connecting new information to previous knowledge, Considering individual interests, needs, tasks, methods and learning rhythm
4. Activity	Hands-on, Minds-on Learning by doing Learning by animation, simulation and playing Learning by playing and designing games (creative learning)	Knowledge must be newly created (constructed) by each learner (= constructivism) Learning is an active process (=progressive education)

Up to now, the COOL Informatics approach has been tested in some pilot projects in primary, secondary and higher education. These projects apply all COOL Informatics principles, but evaluate different main aspects. Table 2 shows an overview ordered by their main aspect (*Informatics – A Child's Play*, *COOL Informatics* and *Brain-based Teaching*).

Time	**Project**	**Aims/Content**	**Target group & level**
Brain-based Teaching			
2012- 14	Brain-based Programming	Increasing understanding and learning success in object-based programming	Bachelor students of Informatics, Economics, Math
COOL Informatics – cross-curricular			
2011/12	Informatics for Language	Cross-curricular learning and projects, applying informatics and computer-supported open learning in language lessons,	Students of a vocational high school for tourism and commerce
2013	COOL Informatics	Developing "cool" cross-curriular units and tasks	Master students in teacher education
Informatics – A Child's Play Raising interest and teaching Informatics concepts in a "cool" and playful way			
2012/13	Exploring and Discovering Informatics	Based on neurodidactics	Students of primary school, 3rd and 4th grade
2013/14	Young children learn from older	Applying learning by teaching	Students of primary and lower secondary school
2014	Informatics-Lab	Developing and testing teaching materials for different subjects	Children from five years on, primary and secondary school, all levels

The following section describes examples for applying COOL Informatics on different educational levels.

Exploring and discovering Informatics in Primary Education

The project "Exploring and discovering Informatics" ("Informatik erforschen und entdecken"), carried out in an Austrian primary school, is an example of "COOL" and brain-based teaching in a lower level of education (Elsenbaumer 2013; Sabitzer & Elsenbaumer 2013).

Students from a third and a fourth primary school class should learn the important informatics concepts and get curious about this area of science. The main aim was to

prepare the children for life, which includes many elements from informatics (Elsenbaumer 2013). The project was implemented from January to May 2013 in 14 days intervals in each class. Each unit lasted two hours and among others the following topics (in part based on Informatik erLeben (Mittermeir, Bischof and Hodnigg 2009)) were included (the numbers in brackets refer to the number of the applied principle of COOL Informatics in table 1):

Hardware unit: During the unit students slipped into the role of specific hardware components and simulated how they work together (2, 4). Also real hardware was shown and could be touched by the students (1). The creation of a memory game represented the conclusion of the first unit (3, 4).

Encryption unit: In this unit students should learn some simple mechanics from encryption. To make this content interesting for the students the unit started with an encrypted text (1), they could not understand. It was started with simple encryption algorithms like Caesar-cipher, which was decoded by using a wheel like in figure 1 (1, 4).

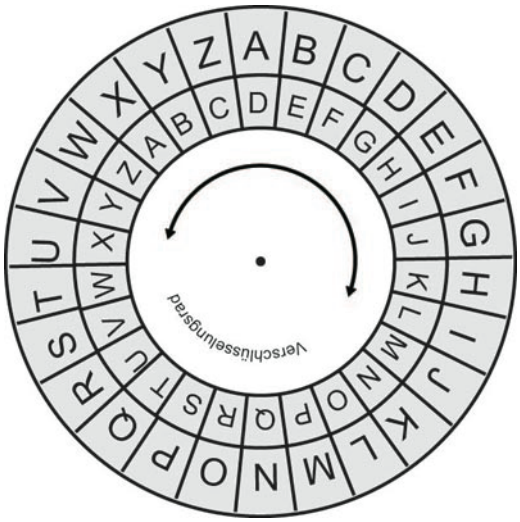

Figure 1 Caesar-cipher wheel.
From: http://qig.itp.uni-hannover.de/quanth/images/b/b9/A3_ceasar_rad_a_d.jpg

Flash drive and text editor unit: After the second unit the students should come in touch with working computers and standard software programs. For this purpose two units were planned. The first of them had the aim, that students learn how to use a USB memory stick correctly and how to store a text-document on them. In teams of three students (2) they had to plug in the USB memory sticks, open a text-document, which included the beginning of a story, with an appropriate editor, add some sentences to continue the story, store the text-file on the USB memory stick and safely remove the USB memory stick from the computer. Then they passed the stick to another group and got themselves a new stick, which contained a text-document with a different story. They had to repeat the process until each group has passed each stick (3, 4).

PowerPoint unit: In the second unit with standard software programs the students should learn how to handle the presentation software PowerPoint. Again the students created pairs or groups of three people (2). One of the students had to have previous knowledge in PowerPoint or at least in the handling of a computer. The task was to

independently work in these groups and to create an own presentation. On a USB memory stick they could find learning videos (1), which described the handling of PowerPoint step-by-step (Elsenbaumer 2013; Sabitzer & Elsenbaumer 2013).

Boolean algebra and logic unit: This unit should introduce logic operators, Boolean algebra and digital circuits to the students. It started with some questions about what the children think that logic and logical thinking mean and if there exists a relation with computers. During the next step a story about a birthday party where only guests with a costume AND a present get a piece of the cake was told. Together with the students the teacher showed how this story can result in a truth table (1). After that the students had to try it on their own (2, 4) and find out how the truth table works when the guests in the story have to wear a costume OR bring a present. The truth tables were filled with child-friendly symbols like smileys for the persons and cards with check marks (yes) or crosses (no) in order to indicate if the condition is true or false. In a further step the children had to write down their own stories containing an AND- or an OR-condition (3, 4).

COOL Informatics in Secondary Education

In a secondary school we focused on Mobile Learning as one aspect of COOL in the sense of Computer-supported Open Learning. As described in (Sabitzer & Pasterk 2014a) we implemented mobile learning in the author's secondary high school of tourism and commerce in three steps. First of all, we checked the equipment of the students and their usage habits concerning mobile phones and mobile learning. Then we offered workshops about mobile learning in language lessons and carried out a cross-curricular project on app programming in Applied Informatics and Spanish. In part the tasks were developed in the Master Course "COOL Informatics – Cross-currricular Concepts" at our university.

Brain-based Programming in Higher Education

"Brain-based Programming" is the name of a project that started with its pilot phase in winter 2012 at the author's university and is described in (Sabitzer & Strutzmann 2013). The main aims of the project were to create and evaluate a brain-based script for beginners in Java programming and to implement and evaluate brain-based teaching methods in an introductory programming course. Interesting for this paper are the structure and the methods, which were used during the experiment. Basic elements for the brain-based courses are especially for this purpose developed brain-based tasks and an adapted lesson structure called brain-based lessons. The exercises contained reading exercises, with for example complete pieces of Java program code and questions about this code or Step-by-step instructions (1, 3), competence-oriented tasks, with a big variety of different tasks to choose from following the student's interests (3), and programming tasks, with one big and complex Java project, which is worked out in small pieces during the semester.

During the lessons the students with good programming skills acted as peer-tutors or peer-teachers and helped their colleagues by answering their questions (2, 3.). The lesson structure was adapted and divided into a asking questions phase at the beginning, to give the students and peer-tutor the chance to work out answers to their questions (2), a discovering phase where the students discovered new content or to

recall topics they already knew with the help of reading exercises or short video clips (1, 2, 4), and finally a laboratory phase, to work on their exercises from the worksheets in teams of two people (2, 4) (Sabitzer & Strutzmann 2013).

EVALUATION AND RESULTS

For the evaluation of the "COOL Informatics" approach, qualitative and quantitative research methods depending on the main aspects are applied:

With questionnaires, informal feedback letters and open interviews with students and teachers in all projects studied the acceptance of COOL Informatics.

The learning outcomes in all projects are measured by immediate questions of the teachers, observation of the students' activities and, in the project Brain-based Programming, by two written exams.

The collected data of the pilot projects allow the following core statements:

- Students and teachers were satisfied with this approach.
- Learning and understanding of computer science concepts could be improved.

Acceptance of "COOL Informatics"

As COOL Informatics is a new approach that requires unusual teaching and learning methods, we were interested in the acceptance among teachers and students, their satisfaction, the preferred teaching methods and tasks as well as the practicability of different aspects of "COOL Informatics" in different schools and on different levels.

The qualitative evaluation of the "COOL Informatics" approach on three levels and different aspects shows the following main results:

(1) Brain-based Teaching

The following main results are taken from different non-standardized questionnaires (at the beginning, half and end of the semester), the official course feedback after the mid-term and the final exam, non-structured interviews with teachers and students as well as a SWOT-Analysis:

- Students and teachers liked the relaxed atmosphere in the courses.
- Students (learners and peer tutors) highly appreciate the possibility to get help anytime and from different people (colleagues, peer tutors, teacher).
- They like the possibility of free choice concerning tasks, topics and material.
- The most useful methods in the courses were discovery learning, peer tutoring and pair programming respectively team work.
- The most useful tasks were all forms for discovery learning: step-by-step exercises, reading corners, video-tutorials, mini exercises with solutions;
- The peer tutors indicated that they learned more than in a traditional classroom setting: They even learned contents exceeding the frame of the actual course content because they had to check the in books or to ask the teacher.
- The preparation of different material is too much work for teachers.

(2) Informatics – A Child's Play

- Child-adequate approach increases interest and motivation.

- The initially reluctant attitude towards informatics of primary school teachers changes after an introductory workshop showing the connections to the curriculum. They are surprised that they already use informatics concepts (e.g. algorithms).

(3) COOL as Computer-supported Open Learning

- Technology-supported learning, especially mobile learning, seems to be more motivating and "cool" than traditional learning methods.
- The relaxed atmosphere in the courses (for teachers and students);
- The possibility to ask different people and the possibilities of choice concerning tasks, topics and material.
- Self-responsibility or free work is sometimes misunderstood as "free and nothing to do".
- Teachers have fear of unexpected questions and technical problems.
- Assessment is difficult.

Learning outcomes

Concerning the learning outcomes we investigated in our projects if
(1) teaching by considering neurodidactical principles (brain-based teaching) could increase understanding and learning of informatics at university level and
(2) children can understand and learn core concepts of informatics when they are taught in a playful way and integrated in other subjects in primary schools.

(1) Brain-based Teaching

The main results for this aspect come from the project of "Brain-based Programming" with the aim of improving learning and understanding in Bachelor programming courses. After a successful pilot phase in 2012/13 (one group), the learning outcomes were tested (in two written exams, the same for all parallel groups) and evaluated in three experimental groups and compared to the four parallel groups as well as to the results of the three preceding years. Summarizing the results of the project it can be said that this concept is more effective than the traditional methods used in the courses up to now. The evaluation of 2014 (Sabitzer & Pasterk 2014b) reveals

- a higher success rate in the practical groups (52% instead of about 40% as usual);
- significantly better results in the first exam (comparison of the achieved points, t-test for independent groups, $p = 0.008$, Cohens $d = 0.42$);
- female students benefit even more (Cohens $d = 0.58$);
- better results in the second exam: The average of achieved points in the experimental groups was 10.73 (control groups 8.64) with a standard deviation of 6.98 (control groups 8.64).

These positive results should be interpreted as only cautiously optimistic. Empirical studies in this context are continuing and a closer look will be taken at special factors like the impact of discovery learning, gender and other personal aspects, as well as to problems during the implementation of the concept.

(2) Informatics – A Child's Play

The learning outcomes of the children participating in the pilot projects of "Informatics – A Child's Play" (Exploring and Discovering Informatics, Young

children learn from older, Informatics-Lab) were measured by immediate questions of the teachers and observation of the pupils' activities. Summarizing it can be said:

- Games and animations help to understand complex topics.
- They seem to support sustainable learning.
- Also young children are able to understand and learn core concepts of informatics.

CONCLUSION

The evaluation results in different schools and university courses indicate that the approach of "COOL Informatics" is not only appreciated by students and teachers of all levels, but also effective if it is taught in an appropriate way, like the projects "Brain-based Programming" demonstrated. The new teaching concept of the same name developed in this project got very good feedback from the participating students as well as from the teachers. The evaluation results further show that the concept is effective and has benefits especially for female students. This may be due to the applied cooperative learning methods, as females are generally more communicative and accustomed to solving problems by talking about them (Coan, 2008). Furthermore it seems that all exercises for discovery and step-by-step learning support the understanding of complex topics and hence also improve the learning outcomes. The gender gap usually observed in informatics education may be avoided if core concepts are taught already in primary schools. The pilot projects of "Informatics – A Child's Play" could not only increase the interest in computer science but also showed that girls are equally interested and talented for this subject. In any case, the gender aspects as well as the successful integration of COOL Informatics in primary education should be studied more in detail.

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