Importance of Learning to Code, Coding to Learn in Higher Education

Anton J. Knierzinger[1] and Boyka Gradinarova[2]

Abstract – **Computer and internet give essential features to our life. Should all students learn programming? The message of this paper is a plea to improve the quality of highest education via bringing forward the importance of algorithms by stating their role in different sectors of our society as well as the learning and teaching process. Algorithmic thinking should be part of all subjects at all levels of education, because it improves the chances of our students in many directions and reflects the responsibility of education for our society. But coding in that sense is different from traditional programming. Teaching coding has three aspects:**

- **a technical approach - what are we talking about**
- **a social approach - why are we talking about**
- **a didactic approach - how are we talking about.**

Keywords – **algorithm, digital society, coding, programming, education.**

I. INTRODUCTION

Let us spring from data. We commonly understand data as information, values or findings, which has been discovered by measurement or observation. Data are object of political discussion in form of data protection or data security. We affiliate their possession with economic power

A definition of an algorithms by Wikipedia is „a self-contained step-by-step set of operations to be performed" either in real life or virtually on a computer. „Algorithms exist that perform calculation, data processing, and automated reasoning"

Anyway algorithms are proposed actions. They occur everywhere in our life, cooking recipes, instructions for technical installations, turn-by-turn directions for a route, there are many other examples. So we all have internalized the concept of an algorithms. By defining them we structure a problem into pieces and doing so we prepare it to be operated in a machine.

Teaching algorithmic thinking conveys two important competences:

- problem analysis and
- problem solving.

Their importance for our life, for science, society and education is commonly underestimated. Algorithms allocate power and distribute chances. Especially because of that we propose that the preoccupation with this topic should be part of education at all age level

[1]Anton J. Knierzinger University of Education Linz, Austria anton.knierzinger@ph-linz.a.

[2]Boyka Gradinarova Technical University of Varna, Bulgaria BGradinarova@hotmail.com

Where in society do we meet algorithms. We identified four major areas, all of them with great influence on our life.

1. Science and technology They have a great relevance in IT studies. But there are numerous examples in many other disciplines where algorithms play an important role.

2. Society and economy Algorithms and their ownership provide clout and power in our society, but they also offer creativity and fun, they facilitate advancement and value.

3. Pedagogy and human development In general (full development of the human being via education) and in vocational training (the imparting and acquisition of specific skills) teaching algorithmic thinking and the knowledge how to deal with coding improves the chances of our students in different ways.

4. Didactics and education Using coding as a principle of teaching improves education by offering new ways of creativity, connection to real life and allow to have fun via learning. It is our experience since the introduction of IT into education that this can intensively change and improve the process of teaching and learning.

II. SCIENCE AND TECHNOLOGY

Paradigmatically we want to have a look on different areas where coding is playing a major role in science and technology

A. Automatisation

Industry 4.0 is defined as the „informatization" of production technology and logistics by machine-to machine communication. It is also named as smart or networked production. Within industry 4.0 robots can take a lot of hard work from the shoulders of their human companions. They work on the basis of cyber-physical systems and what is called the internet of things.

But automatization will reach nearly all areas of our life. That leads to the question: Are we in danger to loose our jobs to a robot? BBC has published a web-site „Will a robot take your job? based on a study done by Oxford University and Deloitte (http://www.bbc.com/news/technology-34066941). Oxford University academics Michael Osborne and Carl Frey calculated how susceptible to automation each job is based on nine key skills required to perform it; social perceptiveness, negotiation, persuasion, assisting and caring for others, originality, fine arts, finger, manual dexterity and the need to work in a cramped work space. Students can investigate the future chances of their profession and find amazing facts.

B. Robotics

Undoubtedly their are numerous fields for the use of robots. It can be inspiring and informative to present them in lesson.

Robots are fundamental of modern military strategies. We find them as drones, secret agents, fighters and helpers for soldiers. Associated with the technology we have to rise questions like:

• Is the inhibition threshold dropping?
• Who then decides on life or death?
• Will less or more people killed in an electronic war?

But robots will play other different roles in the future. They will act as servants, tour guides, play mates for kids, aid worker, lawnmowers and toys. At it we should discuss the following questions with our students:

• Under what conditions should robots replace humans?
• Can robots have human qualities like creativity, real emotion and spontaneity?

We have to discuss what Joseph Weizenbaum [3], famous for ELIZA, the first algorithm with human behavior, turned during the last years into an „old any man" asking: Are we in danger that when robots simulate man, humans are more an more simulating robots? Robots touch very much our self-conception

C. Autonomous Transportation Systems

Autonomous logistics describes systems that offer unmanned, autonomous transfer of equipment, baggage, people, information or resources from one point to another without human intervention. This is a new area for research and development and therefor of great interest for higher education.

Visualization and coding of processes plays an ever-growing role in our society and therefor represent an emerging market. Examples are image editing, the revolution of music industry caused by the invention of the MP3 algorithm or the development of the digital presentation technique. An example of future trends in visualization can be seen in an advertisement for the upcoming video product HoloLense (www.microsoft.com/microsoft-hololens/en-us?video-url=vdeHHP). Microsoft HoloLens is the first fully untethered, holographic computer, enabling high-definition holograms to integrate with your world. It offers the possibility to combine real and virtual objects to one perceived reality. A sentence quoted from Microsoft describes the impact of visualization: „If you can change the way you see the world, you can change the world you see!". According to Marshall McLuhan a change in media technology implicates a didactic commission for higher education

D. Meteorology

Meteorology is one of only two more examples of natural sciences that we show, where algorithms are involved in the process during the last decades. The success in the prediction of weather is mainly depending on the speed of the computer systems and the quality of the algorithms used. The improvement of both factors made it possible to increase the complexity of the models for computation.

IT is also used for the fast processing of the big amount of data produced by weather satellites, the prediction of natural disasters and the online visualization of weather forecasts.

E. Biology

The importance of algorithms in biology is usually underestimated. Without adequate algorithms the decoding of the human genome would not have been possible in a short time. This has big influence in medicine, pharmacology, agriculture and forensic examination. But also IT is learning from biology. In artificial intelligence, an evolutionary algorithm (EA) is defined as a generic population-based optimization algorithm. It uses mechanisms inspired by biological evolution, such as reproduction and selection. Bionics is the use of methods taken from biological systems to the design of modern technology. In robotics the study of bionics has produced efficient designs for robots, artificial neurons, artificial neural networks and swarm intelligence. Algorithms are used for the simulation of biochemical processes and in the workflow management of clinical research. Therefore a lot of European universities offer special studies in bionics. They can be seen as an example for the improvement of higher education by an interdisciplinary approach.

III. SOCIETY

There are many samples how algorithms influence our society and sequent our life. For illustration it is enough to demonstrate three of them.

A. Politics

The participation of citizens in political decisions is based on the following mechanisms in the political process:

• Elections

It has been a long debate in Europe to what extent voting can and should be maintained by IT. But the fundament of free elections is the trust of the participating citizens in the system used to collect the votes. As people are always confronted with the misuse of their data in Austria there is no electronic voting at the moment. In Bulgaria there is a living public discussion on electronic voting.

Grassroots democracy

At the end IT supported ways of collecting the public opinion could lead to a stronger civic involvement. But the attempts of the Pirates Party to foster civic participation in Germany using a software called „Liquid Democracy" shows that there are limits and their violation obstruct the political process and the contribution of a political movement, because sometimes it takes to much time to come to an end.

• Open data and open codes

We need ways how responsible citizens come to the information which they need for participation. In the EU we see an ongoing debate on how the access to governmental data should be organized. The majority of the algorithms we are subject to is not in possession of governments but in the hand of a few global players in IT industry. We propose a discussion of their role and how the rights of the people on data and the algorithms used for their processing can be saved.

• Communication

For example the political processes in northern Africa in the last years have shown the importance of open communication for a progress in society

B. Economy

Among the various possibilities of the use of algorithms in economy we want to present only two but very characteristic examples:

• User profiling

User profiling is used in different ways. On example is individually designed advertising. To do this you have to collect data about your clients, but the main factor for success is an algorithm for a suitable analysis. The most extreme use of client profiling we found in Switzerland. COOP tried individual pricing. The price of a specific good was not only determined by time and the location of the shop but also by the analysis of the buying behavior of the client detected by clandestine algorithms. This project has been terminated because it caused a storm of protest.

• Share market

A considerable part of the trading of shares is currently done by algorithms. This led to a competition concerning the quality of the algorithms used between the major players in stock market. The quality of the codes used has a big influence on the performance of trading companies. The CEO of an Austrian bank told us that he prefers mathematicians instead of economists in his treasury department.

C. Arts

The influence of algorithms on arts is widely unknown, but there are interesting and numerous examples for the use of algorithms to generate artistic expression. Artists use algorithms since ancient times. For example you will find them by Leonardo da Vinci, Bach, Mozart, and Escher. Beside visual design algorithms are also used for computer generated music and poetry today.

Linz in Austria has a special and worldwide know center for electronic art, the AEC - Ars Electronica Center. It's FutureLab is a place for researching and trying out new cyberarts technologies. Once a year, Ars Electronica invites artists, scientists and researchers from all over the world to a conclave in Linz to confront a specific, interdisciplinary theme in the context of speeches, workshops, exhibitions and symposia. A yearly competition called u19 is dealing with questions like: Who decides, how the next generation will be in 20 years? Which technologies will be used then? How is our society developing? Which artistic ideas can help us?

IV. PEDAGOGY AND HUMAN DEVELOPMENT

Beside all the societal, economic, creative or somehow other good reasons to talk about algorithms in university courses, there is one, and we think to is probably the most important for teachers, „Dealing with algorithms in education increases the chances in life of our students.". And we can see this in various directions.

This affects at least four areas of competences: According to our experiences during the last decades and proven by many studies, teaching coding and algorithmic thinking leads to an enhancement of the competences of our students.

This affects at least four areas of competences:

Professional Competences:

•cognitive competences, because they learn how a decision as a structure of choice have an influence on an algorithm

• analytic competences, because for the solution of a problem they have to isolate, analyze and structure the necessary information

• logical reasoning and faculty of abstraction

• problem solving • selection and application of suitable tools

Methodological competences

Students gain abilities in the use of IT-methods, the usage of digital media, acquisition of information and their evaluation and visualization.

Occupational outlook

The preoccupation with coding, the work on computers and the general competences in problem solving lead to proficiencies far wider than traditional IT-training. The excogitated dealing with algorithms in university courses lead to

• a widening of the spectrum of professions seen as possible and / or worthwhile

• improves the chances on the labor market. Students gain abilities in the use of IT-methods, the usage of digital media, acquisition of information and their evaluation and visualization.

Personal Competences

Beyond doubt we could observe an alteration and enhancement of the personal competences of our students and the kids participating in the computer camps in Bulgaria touches especially their self-confidence and the self-assessment of their own prospects [3]..

The better and proper handling of digital media facilitates the most important competences in job and life in general. This can be demonstrated by the findings in the evaluation study of the „Power Girls Project 2013" in Upper Austria done by Alfred Weinberger from University of Education Linz. Power Girl is an initiative of Education Group, a governmental agency aiming the integration of media and technology in schools. The results of the yearly evaluations since 2008 show clearly the positive effects of the engagement in technology of girls on occupational and personal competences.

Girls who participate in the „Power Girls Project" boast

• a more emancipated and stronger non-traditional role model,

• value their own technical competences higher,

• are more interested in technical-oriented jobs and qualifications and

• choose more often higher technical education (schools, apprenticeships) than girls not taking part in this project.

V. DIDACTICS

When we started to integrate IT into education at the beginning of the eighties of the last century, we could feel that we had received a medium for revolutionizing didactics at

school and university level. But during the years we unfortunately lost our feeling for this mission and a concept of IT as a medium for better employment gained ground. There are several reasons for that and it is worth to discuss them in order to redesign the whole process

We see that

• IT lost its special position

• persistence of the education system • a wrong selection of content

There are two main reasons why Informatics lost a large portion of her attractiveness and the number of beginners in IT studies in Germany and Austria is declining in the last years.

1. The abnegation of core topics of IT, like programming, and the concentration on application software might accommodate the interests of economists. But this doesn't fit to the expectations of our students. They want to work creatively and choose their tools by themselves.
2. We do not pay enough respect to McLuhan's subtext „The medium is the message". The message of coding is that it needs its own didactics. When observed this can lead to fantastic results.

To support this view we want to show a model for creative learning presented by Mitchel Resnick. He was working with Seymour Papert and is the developer of the educational programming language LOGO. Resnick proposed a model with four columns all starting with the letter P, the 4'P Model for creative learning:

- Projects,
- Peers,
- Passion and
- Play.

Resnick developed a new version of LOGO called SCRATCH designed only for creative learning by offering a very different approach to coding. Coding is not any more a set of technical skills but a new way of thinking and personal expression.

Projects

„Scratch was designed with projects in mind." [5] Students learn better through active working on topics meaningful for them. Learning is more efficient via projects and when using proper tools. This diversity of projects is a reflection of the diversity of interests of young people. Therefore instructions should be:

- cross-disciplinary • project-oriented • targeted • have a practical attitude
- and first and foremost be creative.

Peers

„Encourage collaboration, sharing and help children to learn to build on the work of others. Coding shouldn't be a solitary activity". [7]

Learning thrives as a social activity, when people exchange their ideas, work on common targets and share their results. We believe that interaction with peers should be a central element in the learning process. So much learning can be exciting when it is team-oriented and appropriate to age and background. When teaching coding we must also focus our attention to choose the right level of abstraction.

Passion

Teaching should raise enthusiasm, reason the doing and engender creativity. When working on projects which are meaningful, challenging and kidding students work harder, longer and more efficient. That leads to success and sustainability of the learning process.

Play

Playing is the way of teaching that will support the creativity of our students. Learning to code should support experiments, lead to personal limits, urge the students to rise and always allow to try new ways..

VI. CONCLUSION

At the end we want to return to the starting point of the history of IT didactics and finally propose our conclusion and the idea which underlying this paper.

BASIC (an acronym for Beginner's All-purpose Symbolic Instruction Code) is a general-purpose programming languages whose design philosophy emphasizes ease of use. In 1964, Kemeny and Kurtz created the original BASIC language at Dartmouth College. They wanted to enable students in fields other than science and mathematics to use computers and to mediate them a feeling for algorithmic thinking, problem solving and the impact of algorithms on their professional and personal life. (see Wikipedia)

We see two reasons why we propose that we should again put a spotlight an coding and algorithmic thinking in tertiary education today:

• Algorithms have an underestimated power in many areas of science and society.

• Coding offers new ways of creative learning

Sometimes a step back can be a step forward.

REFERENCES

[1] Burton, A. (2013). Dolphins, dogs, and robot seals for the treatment of neurological disease., Lancet Neurol. 2013; 12(9):851-2 (ISSN: 1474-4465)

[2] Knierzinger, A. (2015). learning to code,coding to learn - The World of Algorithms in School, E-Learning Fachtagung, presentation, Linz

[3] Knierzingen, A. Gradinarova, B. Learning to code, coding to learn the world of algorithms in higher education

[4] Marschmann, H. (2008). Joseph Weizenbaum: Der zornige alte Mann der Informatik. Artikel in „Der Spiegel

[5] Maloney, J., Resnick, M., Rusk, N., Silverman, B., & Eastmond, E. (2010). The Scratch Programming Language and Environment. ACM Transactions on Computing Education (TOCE), vol. 10, no. 4 (November 2010)

[6] Repnik, R., Robic,D. Phisics Learning in Primary and Secondary Schools with Computer Games- An Example-Sngry Birds, E-learning Instructional Design, Organizational Strategy and Management, InTech,2015.

[7] Resnick, M., & Siegel, D. (2015). A Different Approach to Coding. Bright/Medium.