Michael Herczeg*

The role of digital technologies and Human-Computer Interaction for the future of education

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Abstract: Over the last 50 years education has been transformed by digital technologies. Many efforts have been made to create and apply "digital" teaching and learning methods, tools and platforms. The last 25 years of computer-based education can be characterized by the availability of digital information sources and the implementation and operation of digital learning management platforms based on the Internet. The question about further meaningful and effective progress in the next decades is openly discussed. Many expect strong influences and changes from artificial intelligence systems that generate contextualized information from various sources. Some see interactive virtual worlds expanding and partially replacing the physical world. Many believe in the further development of learning management and communication platforms. Others do not expect much valuable change at all due to the slow pace of complex educational systems with recent studies even showing a decline in the quality of educational outcomes during the last five years as a result of even too much digitalization in education. This paper discusses these positions with an emphasis on the roles of humans and computers and their interfaces, i.e. Human-Computer Interaction, for future learning and teaching with rapidly changing information technologies in the next 25 and 50 years.

Keywords: future of education; E-Learning; Human-Computer Interaction; artificial intelligence

1 Introduction

In an age of ever more powerful computers with thousands of new applications every few months, how can one predict what computers will be able to do in the next 50 years and how they will be used for education? Looking back: are we learning differently in the "digital age" than we did in previous times? If so, what are the major changes? One is tempted to say: *"Everything has changed. Even when I use my smartphone the situation is completely different to the past because I have more information at my fingertips than ever before."* Some might even believe: *"In a few years, the successors of Pepper and ChatGPT could be 'doing the learning' instead of the people."* They might be our *"Servants of Learning"* or our *"Knowledge Navigators"* as Apple's CEO John Sculley called them in a company's feature video nearly 40 years ago, referring to earlier groundbreaking research done by Alan Kay,[1] Ted Nelson[2] and Vannevar Bush.[3] How will learning take place in the future? Will children continue to sit on uncomfortable wooden chairs learning the location and length of the Amazon, calculating with Ohm's Law, or memorizing, at least partially, what is written in our Constitution? Instead, they might go online to certain digital platforms with tons of video clips made or moderated by "influencers", ask a future "KnowledgePedia", or talk to some variety of "Generative Pre-trained Knowledge Transformer", today's so-called Artifical Intelligences (AIs), and find out what they "think" is important for us.

Let us look at the current situation and start with an imaginary walk through a pedestrian zone. Many people there stare down, not at the ground, but at their smartphones. Hardly anyone of them knows or wants to know how long the Amazon is without consulting Wikipedia or similar Internet information sources. Most of them might not even have a rough idea in which countries the Amazon is actually located, or might even think first that it's just one of the big online stores. Hardly anyone remembers Ohm's Law and even fewer know what is really written in our Constitution and what it means for our daily life. You can look it up on the web if you need it, right? However, understanding the influence of large rivers and forests on the climate, what consequences the laws of electricity predict for the calculation of cryptocurrencies, or why we should better keep our hands off our basic laws cannot be found on a certain website. Such knowledge and competences, or

***Corresponding author: Michael Herczeg**, Institute for Multimedia and Interactive Systems (IMIS), University of Luebeck, Ratzeburger Allee 160, D-23566 Luebeck, Germany, E-mail: Michael.Herczeg@uni-luebeck.de.
https://orcid.org/0000-0003-4620-5186

at least meaningful fragments of it, should be a result of our education. We can critically discuss the value of looking things up on the Internet when needed, using examples of big and urgent issues for the future of humankind, such as nature and climate, economics and technology, or history, politics and the humanities. And what about everyday topics like nutrition, health, money, house construction or gardening? What about basic skills such as reading, writing and arithmetic? Ted Nelsen concluded – even before the WWW was available for looking things up – *"the moment you establish a curriculum, you've lost it"*.[2] What should be the basis of education in our future? What should be taught and what should be looked up on demand with some technology? What will be the future role of humans and what may computers contribute to education? Do we really need a big change in education and should computers play a central role in it?

Since the future does not just arrive, but needs to be designed and shaped, we cannot ignore the question of what schools, or education in general, will look like in a few decades in an even more medialized and digitized world.[4–6] Looking into recent studies in Sweden about the development of reading skills, there are hints that current ways of digitalization are naïve and wrong targeted measures showing not much improvements but measurable disadvantages compared to the classical means like paper-based books. As a result, Sweden will even stop proceeding implementing the proposal for the digital strategy only recently developed by its National Agency for Education.[7] Are we facing the end of digital education, as we have recently envisioned it, even before we have been able to complete significant early steps of an educational digital transformation and are we at the beginning of a new way of thinking about education? This comes as a shock and is reminiscent of Neil Postman's discussion more than 25 years ago about the rise and role of technically mediated media, at this time especially television, but also early computers, which seem to be weakening the ability to read, write and understand the narrative and the discourse.[8]

2 Educational technologies in the last 50 years

More than 50 years ago, mainly in the 60s and 70s of the 20th Century, the advent of digital computers inspired many fantasies about our future. One of these was the transformation of our educational systems into a world of computers supporting learning and teaching in a kind of lead function going so far that it was even discussed whether teachers might be replaced by computers. Then the first real computers were brought to schools, some for play and some for teaching programming. After that, not much happened in schools regarding computers except different experimental and not very promising educational scenarios and settings.

> We are writing the year 1974. Marianne, a 13-year-old girl, has just started 6th grade. The new school year brought new textbooks. Of course, they are not really new and have already been used by her predecessors for several years, showing personal markings and notes. But they look more interesting than last year's books. While flipping through them, Marianne has already found new, seemingly complicated stuff about math and physics. Geography doesn't look uninteresting either; it will be about Africa. What's it like there? She recently saw on TV – her parents just bought a color TV – that there are no nice schools and classrooms there; the children are taught in simple barracks on bare ground. Her school looks much better: pretty classrooms with self-decorated walls and windows and a nice foyer to meet other students. But she has to admit that learning there is mostly boring. Her English teacher always talks as if he was born in London or Oxford; he just talks funny. She hardly hears people speaking English like that on TV or radio. TV is her window into the world. Biology seems a little better because the class has a school garden where you can actually try, see and taste how vegetables are grown. Math looks strange and she has not much of an idea what it will be good for. She kind of learns most of it in advance. Will it ever be relevant in her life?

At about the same time that Marianne is thinking about English lessons, carrots in the school garden and strange math formulas, universities and research centers around the world are developing the next generation of schools and universities. Physics and chemistry lessons, among other fields, shall be taught on touch-screen electronic plasma displays connected to large mainframe computers. PLATO, the Programmed Logic for Automatic Teaching Operations running on some of the largest mainframe computers, was designed to lead the way in digitizing schools and universities. Other approaches and platforms for *E-Learning* emerged.[9–11] The further development looked quite clear: more digital content on personal and later mobile computers for self-directed learning without much need for teachers. So the future of education, then often called *Life-long Learning* mostly in political contexts with an even more promising horizon, seemed to be very much about how to get rid of the blackboards and the hard wooden chairs as well as the schools and the teachers.

3 Educational technologies today and tomorrow

We needed the COVID-19 pandemic to really try E-Learning on a very large scale in educational institutions all over the

world at once: curricula, teaching and learning materials and communication channels on prepared web pages and additional content found with the help of some intransparent search engines. During this time the importance of communication and exchange platforms for the general population in work, education and leisure was discovered and tested. A scenario might help to remember:

> In the year 2021, Fritz, 20 years old, is studying computer science at the local university. COVID-19 grounded him with his notebook and smartphone in his student dormitory. Within a few days, he has to prepare a seminar and give a "virtual" presentation about "Current Drafts for the Future Standardization of Internet Communication" through the videoconferencing system of his university. Quite a dry and complex topic, but Fritz hopes to find some helpful text, tables or images in the internet. He actually finds a whole bunch of information about the topic in the web; however some perhaps most interesting white papers of companies and conferences are behind paywalls, where he has no access. He thinks for a moment to let the recently discovered ChatGPT create the presentation for him, but there are a lot of strange discussions going on about ownership and copyright stuff. So he prepares in the old style using his presentation application. He opens a standard template and starts to copy and paste some text and images he already found through a search engine into the empty slides. Font size is jumping depending on the text length and some images seem to be of the wrong resolution. It first just looks like a mess of text and images. For several hours he cuts, pastes and resizes until it seems to be good enough for now, but actually there is not much time and motivation left. Next he will need to upload the presentation into the predefined task area in the 'Learning Management System (Moodle)' prepared by his professor for the seminar. He finally logged into Moodle and tried to upload the presentation. He then discovers that he can only upload PDF-files, so he goes back the presentation application exporting the slides to PDF. When checking the PDF generated he finds some graphics got black or disappeared. After a while he found out that he has to use another PDF-generator that needs to be installed on his notebook first. Even being a future computer scientist he hates to install new software since most of the time you run into some trouble. This time it worked well and finally his presentation is available in a completely visible and readable PDF. Wow, what a success after a nearly a whole day. He tries to upload again. "Maximum file size exceeded" …. He hates it. Another hour later with optimizing the presentation size, Fritz finally makes it to upload the presentation. A week later he logs into the videoconferencing system for the seminar. Right after starting the software he could not hear the other participants and after some chat they tell him that they cannot see him. After playing around with setups and the USB-connector of his webcam he can finally hear them and they can see him. What a relief. Even more strange, during the presentation the other participants have to mute their microphones and to switch off their cams because of the bandwidth. So only he and his professor can be seen in the conferencing system while he is giving his lonely talk from home. At least after the talk some participants clap with funny virtual hands and discuss some questions. He finally made it, but Fritz is not really motivated for his further studies …

Today, telepresence through videoconferencing, recordings of classes, lectures and presentations, and even virtual exams are widely practiced and can already been seen as some "standard". However, like in the case of Fritz' seminar, interest in attending virtualized school and university courses soon began to wane. Cameras and microphones are often turned off by students in virtual classes. It is as if you put a brown paper bag over the heads of the students in the class and sometimes over the heads of the teachers as well. In fact, learners do not show much interest in other learners in such contexts, unless you force them to cooperate in teamwork exercises. It seems that it is simply not smoothly running and motivating to learn in a virtual classroom. Too much learners prefer reading texts and listening to videos on their own. At the end, they choose to watch a video fast-forward, which is – hopefully – enough to pass the exam.

The pandemic is more or less over. What remains? We got different platforms with similar functionality. They get updated with more and more features until users cannot find the basic functions anymore, like where to turn the microphone on or off, how to wave their hand or especially how to install their equipment right. We ended up with expensive and complex digital infrastructures without much addictive potential and poor or questionable usability qualities. The worst indication, there is no clear evidence that more effective or efficient learning takes place while using them;[12] quite the opposite seems to be true, as measured learning outcomes are declining. The OECD PISA 2022 study points to ongoing educational disasters in even most so-called developed countries, including our own. This fits quite well to recently published evaluations in Sweden.[7] The reasons seem far from clear, but no overall positive progress in education through digitalization can be detected. After the evaluations it was even proposed to switch back from computers to printed textbooks.[7] But are not we coming from classical books and other paper-based materials in schools with questionable success? Are all these the signs for the *"End of Education"* in the traditional sense;[8] education that does not fit into our current world anymore?

Even the widely used Wikipedia, a primary source of information for many, may soon have to be shut down because not enough users, private or public institutions are willing to pay for what has always been free content of rather undefined quality. There are only a few hundred thousand paying members for the four billion user hits per month. The overall quality of content on the Internet, which is freely available for educational processes, seems not to improve over time without paying a price. More quality means, at the time being, more organization, paywalls and

subscriptions. Alternatively, you can go to more or less open discussion forums and ask online gurus or those who look like such. The answers are usually sobering as to phrasing and quality. Social platforms deliver faster, but rarely better. The *"Wisdom of Crowds"* predicted 20 years ago[13] may have already passed its peak, as answers do not seem to get better by simply asking more people. And who can tell right from wrong?

What remains are improved search engines to manage the mass of unstructured information stored in the Internet, with more and more content being inaccessible, blocked or rendered unusable by cookies, pop-ups, CAPCHAs, security queries and other dubious web interaction modalities. At the same time, it is becoming increasingly difficult to determine the source of some information. This is the result of complex or even secret algorithms as well as romantic beliefs about where, when and by whom sufficiently reliable information has been created and provided. The current leading and we might better call it the bleeding edge is said to be ChatGPT and similar so-called generative AI systems. At first glance, these systems appear to be intelligent and even pretend to be so. They proved to be quite helpful to some extent when looking for lexical or syntactical structures and patterns like spelling, grammar, sounds or images. They are able to analyze, generate and translate, which seems to make them even universal in a certain sense. First discussions even lead to perceptions and beliefs that these systems are the first encounter with "real AIs" showing common-sense and abilities to be "creative". At a second look, they are increasingly recognized as mere parrots, i.e. syntactic and probabilistic shaking rhyme machines that babble smarter than they actually are. They seem to be a kind of reinvention of ELIZA,[14] only much more powerful and versatile through more data and highly distributed and cached higher computing performance. Such "AI" is currently seen both as part of our future in a positive sense and as a highly problematic threat to education and other areas. This reflects both hope and fear about perhaps upcoming "truly" intelligent machines.[15] However, large and deep probabilistic language models (Large Language Models or LLM) are not automatically large and deep knowledge models (knowledge-based systems, KBS) capable of reasoning, so we may have to wait a few more decades for the latter. Perhaps 50 more years will help us get much closer to what we expect today, just as we thought 50 years ago. As an alternative for the future we may just don't care anymore about the difference between truth, knowledge, information and probability. One interesting point is that at least theoretically the least probable code or production is of the highest informational value, which means that theoretically the most probable next word contains the least information.

The future is always largely made of the past. An e-book is still a book, just with a few more features, cutting down fewer trees while producing more metal and plastic waste. A videoconference is still a technical solution for communication between some people. The neural and probabilistic AI engines, like the earlier digital simulations, are still unilluminating algorithms that pretend to be simulacra of human intelligence[16] while at the same time exposing the obvious stupidity of the machine by just guessing the next most probable word without understanding the meaning of the sentence generated. The situation is best explained when we try to identify the source of the information and the medium for the communication. Mechanical responses expose themselves as media rather than as sources of knowledge. Marshall McLuhan waves when concluding that the *"Medium is the Message"*,[17] later reformulated to *"The Medium is the Massage"*,[18] which hits the point even better. Human knowledge develops when it is constructed by humans for humans on carefully cultivated soil. It is not self-generating and truth is not the same as probability. Teachers are more than media and more than mediators. They can explain why they know or believe something and why something seems important for students and our culture. Most teachers can identify and evaluate sources and are always themselves, as human identities, authentic, even when they are wrong. They know the difference between a hypotheses and a proved fact.

Digital machines do not just exist to be bought off some shelf. They have to be constructed, designed and their mechanisms, algorithms and results have to be explained and evaluated. AI does not invent itself either nor does it replace human competencies when it proposes a trajectory in traffic or when it constructs answers for educational purposes. When we look at the achievements in education and especially education technologies of the last 50 years, are we on the right track? Where could or should all of the approaches found lead to? Do we really need to go back the printed book or do we just need improved digital tools proceeding from where we are? Is there an alternative we could be heading to?

4 Educational technologies for the next 25 years

What can we expect for the future of education when extrapolating past and current developments, experiences and goals? The good news is that the future of education will not just happen and we don't have to wait for it. It has

to be and will be constructed and designed based on experiences, capabilities, economics, research agendas, visions and beliefs. We are already on our way and it is very unlikely that available long-term goals as discussed and partially achieved after 50 years of research, development and application will be given up, even when solutions have been recognized as showing disadvantages like for example e-books compared to printed books, videoconferences compared to face-to-face meetings or generative AI supporting reading and writing. It therefore can be expected that the stronger lines of development will continue and that new developments will be more or less successfully merging or replacing older approaches after a longer period of testing. And we remember that technological development has always been driven by weaknesses, goals and chances. Let us try a future scenario and then think about some abstractions:

> We are writing the year 2049. Luca, an 18 year old young man studying 'Human-Home Systems', is preparing a seminar contribution about 'Barrier-free Smarthomes'. He received the presentation template trough the 'Learning Support System (LESS)' of his university. Now he asks the system to come up with some proposal for the structure and after some discussion with his 'Personal Artificial Study Assistant' they agree about the structure of his talk. He likes to present the details in a naturalistic rendered 3D model of a modern house. This seems to be quite easy since he already has a model from a lecture last week, which he likes to extend by some animated updates. His presentation system asks whether he likes to work on the 3D model through the large 3D screen in his room with some dynamic visual augmentations through his digital glasses. He confirms and then modifies and roughly places his additions with some gestures until they can be seen quite well. They got automatically adjusted to the 3D model. The extended model is visualizing the house's 10G WiFi network connected to the household appliances, air conditioning, mobile cleaning and service robots and finally to the cross-reality communication and entertainment system. The presentation especially highlights all barrier-free concepts for movements and interactions within the home. They all are integrated into the local and remote controllable digital twin of the house through different interaction modalities like gesture and speech. The system creates some links to the text, image and sound sources he used with automatically granted copyrights all trough creative commons and sources paid for by his university. In the presentation mode he finally flips through the storyline with an automatically generated voice and some for the audience hidden visual hints just for his own talk. After doing some final changes and finishing to the presentation it is saved in his personal cloud space and linked to LESS for the later presentation. A few hours later he receives an appointment from his professor to discuss his presentation with some hints for improvement. He and his teacher use the VR gaming mode with their personal avatars meeting and discussing in the virtual 3D home of the presentation. After the meeting he finalizes and renders the presentation into a reusable learning module containing all links to media, sources of information and permissions for later reuse.

Having such a scenario in mind, what are some probable lines of further conceptions and developments for the next 25 years to make this happen? We might need:

- Learning Management and Support Systems (LMSS) with the full range of digital media like text, images, sounds, 3D models with functionality for virtual reality (VR) and media overlay structures for cross reality (XR);
- communications and telepresence in media environments for any XR setting for meetings and conferences;
- personal assistants helping with the use of tools and the access to information;
- generative production systems finding, adapting and connecting media into new or higher-order media constructs by discussing the results and changing them interactively together with their users;
- automatic references to ownerships and copyrights for content with functions for clearing or paying royalties for ownership;
- pervasive and interactive XR devices connected to media repositories like the LMSS with user interface integration modes enabling the users to connect and use these devices without caring about networking, media types, resolutions or other technical details.

All of these requirements seem to be not that far from today's technologies; however in the past the integration and interoperation of digital technologies was always an expensive and time consuming challenge. By further standardization through public and scientific standards, or through the sheer economic power of current or emerging companies creating them, it can be expected that we will reach a much higher level of compatibility and comfort for mixing digital technologies in the future. Thus real Plug & Play in a very general sense may become reality for much more people than today. Another important issue is the general availability and integration of digital technologies for private and public use, especially reuse in the educational area without creating barriers when mixing personal and specialized educational infrastructures like using personal mobiles in any context.[19] We will not have to discuss anymore about the availability of standard computer or networking technologies in educational institutions. However, specialized and higher quality infrastructures will have to be provided by these institutions like for special forms of teaching or certain practical work in labs. Such a development will create the space to think about the real issues for future education instead of talking about basic infrastructures like WiFi or mobiles in schools like today.

5 Educational technologies for the next 50 years

Believing in technological developments for the next 25 years like discussed above, what will be the real and more important issues for future education and what might be expected for further 25 years till 2074? Let us revisit our last scenario and focus on education in the large:

> Alice decided in the age of 14 to become an 'Architect for Personal and Sustainable Ecologies for Living'. Alice was born in 2060 as a European Citizen. In the age of 3 she speaks basic English, German, Spanish and Chinese fluently and a few years later, with the help of her real-time translator, practically any other language of the world. That was quite easy and barely noticeable as she learned these languages starting as a 2 year old child in the Kindergarten Communication Center as well as in her personal room at home that can be connected to any other digital communication space in the world. This allows even young children to meet, talk and play together in peer groups all over the world. Alice loved to build little houses with bricks on the floor as well as on her foldable 3D tablet. Later, at the age of 4 she used the much more realistic Home and Gardening Online Planner Systems, called HOPS, to layout her playhouse and synthetic garden with self-constructed furniture, plants and animated animals through the digital cave of her room. She can talk to HOPS and live in this house and garden using the pair of 3D augmentation glasses, gloves and, a recent present from her grandparents, a special body suit sensing some of her movements connected to HOPS. She can meet with other kids in this house and garden and play together; however she likes to be with her friends in the Kindergarten and later in the School of the same Local Education Center close to their home. And she loves the real house and garden of her family, which is less fancy but much more touchable and smellable compared to what she creates with HOPS. At the age of 10 Alice is already member of a group of young consultants for the constructers and partner companies of HOPS discussing her builds, ideas and wishes for better play. They call her a HOPS Design Scout and set up very funny remote meetings in her self-made environment. She even won some prices for her fancy playhouse. The good thing about HOPS is that she can talk to the system and ask questions, like "Help me to set up a flower bed with blue and not poisonous flowers that are liked by bees and beetles." HOPS then shows her preselected flowers from different real plant families in 3D interactive videos. HOPS is able to explain why these plants are good for insects and whether they will grow well in her family's real garden. HOPS is connected to something they call the WORLDNET. She often takes interesting information and artifacts from there and she already contributed her own findings and builds. In the world of Alice, people only rarely use the terms teaching or learning. It is more about real and virtual things that can be studied and designed together with her educators and the never sleeping WORLDNET. As already said, in the age of 14 Alice decided somehow, to become an architect and her parents fully welcomed and supported her aim by enrolling her into the school track of the Academy of Sustainable Architecture located in another country, where she can enroll as a Junior Student as soon as she turns 15. She can start her studies from her home but she might really be there with other students after finishing school with 16.

What can we draw from this little optimistic story about the future? The educational system needs to become seamless from Kindergarten through School and University to Companies like in the case of Alice. This is not only necessary for enrolments, courses and degrees, but much more for natural, pervasive and authentic post-constructivist *Lifelong Teaching and Learning*. Post-constructivist is meant in the sense of individually build knowledge structures related to real people and real life.[6]

Digital information and media need to be based on connected domains of knowledge through *Knowledge Media Management Systems (KMMS)*[4,20] within a *Semantic Internet* called the "WORLDNET" in our final scenario. Children like Alice can start with low or no recognizable thresholds becoming playful highly involved, then take new steps in width and connectivity of the knowledge with no walls separating domains or people. After reaching and mastering some defined level, the next level of abstraction and complexity with new methods and capabilities is offered and can be explored and mastered.[20] Learning has to be playful, open, social and global. Schools will need to follow knowledge and not vice versa like today. Curricula are an outcome, a personal biography of knowledge and capabilities, and not a precondition of education outdated at the time they are set and published. The knowledge domains themselves represented by computer-based semantic representations need to provide up to date scaffolds of learning.

Interactive Media are connecting the knowledge representations to human senses creating *Knowledge Media Machines.* Artificial Intelligences of any type will be disenchanted and strengthened as soon as their methods will be communicated and taught in respect to their power and limits within such a framework of knowledge. Through this, computers will change into real *Knowledge Media Machines*[20] instead of being *Databases, Number Crunchers and Magic*. *Human-Computer Interaction* will be one of the most important mechanisms of daily life in an increasingly complex and complicated world of connected humans and machines with always limited resources. Education will have to create competencies in using these *Knowledge Media Machines* to solve daily problems anytime and anyplace. *Mobile Computers* networked to *Distributed and Trusted Repositories* with flexible and reusable *Rich Knowledge Media* [19] access will be one of the key technologies.[5,6,21] In the area of simulations for learning, the development of *Virtual Worlds* will proceed to even look and feel more important and even more real than the physical world.[22]

However, if they have no relation to the real world they have to be clearly marked as being fiction and not the replacement for reality.[16] As Marshall McLuhan pointed out, *"we insist on visual metaphors for great many everyday expressions"*[18] with the result that we trust the visual more than the writing, and the writing more than the spoken. So in the end the visual will be the most deceiving. The consequence must be that any media, visual even more than text, always need to be connected to knowledge and its sources as long as it is relevant for living. This can be best done through the direct and natural connection of media to the physical environment through *Mixed Reality* technologies.

As education, work and leisure become increasingly based on digital technologies, the absence or failure of digital tools for even a few moments will be perceived as a complete loss of control. Applied to the increasingly global human and as well externalized knowledge of the world, this means that we must and will take precautions to ensure that proven valuable sources and applications cannot be lost. This will be realized not only through highly persistent storage on stone or glass materials that will last for thousands of years, but also through 24/7, i.e. always available and highly redundant information and network systems in the sense of an *"Always-On Web of Culture"* representing and reflecting human knowledge represented by the *Knowledge Machine Machines* as discussed.

In addition to being passive sources, some of the digital applications of the *Knowledge Media Machines* will not only interact but also communicate with us. We already know that such *simulacra* will not always reveal their true nature as expected.[16] In future it will become increasingly difficult to tell whether we are dealing with a real person or a convincing simulation. This may be perceived as being irrelevant to the person seeking information, as long as the content is believed to be relevant and authentic. But not only for ethical reasons Human-Computer Interaction must always render transparently, whether it is mediating *human-to-human* or *human-to-technology interaction*. Only authentic sources enable us to question information provided and to take responsibility for its application.

Hopefully, in the future people will continue to ask critical questions and will be able to participate in meaningful and critical dialogs.[8] Whether they actually do depends on their education. This closes the circle and is a natural principle that makes them human and responsible what they do and what they aim for. Just as we do today when reading a book, people will ask in future about the machine and its output, mainly by whom and for what purpose it was created. In other words, what was the input or the question of the output generated and what is the rationale? Digital parrots will always be able to deceive if we do not make the digital transformation, its mechanisms and technologies an integral part of the educational system, but instead allow ourselves to be amazed by cleverly designed digital innovations or illusions. Therefore, people must not only learn with computers, but also *learn about computers and knowledge technologies,* how to construct and what to use them for, in the best case by being able of deconstructing and reconstructing them on a meaningful level. This may be the future main educational goal that more or less automatically results in curiosity, creativity, understanding and abilities to decide and act in a complex world.

6 Summary and conclusions

Digital educational tools will continue to support the processes and content of *Lifelong Teaching and Learning* more than ever before. The current focus on processes like learning management will shift more to the content, its meaning and its real-life relevance. The masses and *mixture of human- and machine-generated information* as sources for knowledge building will create new demands to identify and clarify their origin, ownership and authenticity. More information does not mean more and better knowledge, so the selection of the sources of information, the dynamics of the curricula and the application of knowledge to solve problems in a complex world without creating larger ones will be the challenge. So-called *Artificial Intelligence* will neither take the lead nor will it be the reference. Technology will be disenchanted one more time to make clear why it has to be made for bright and alive human beings and not to create self-referencing shiny artifacts even when more machines will be constructed to look and behave like humans. These simulacra are not necessarily reflecting the reality, but creating their own hyper-reality and their own sense of truth. *Real and Virtual Worlds* will be mixed into *Mixed Realities* that have power to strengthen or to destruct the foundations of daily life connecting human senses to physical and informational worlds.

As a moderating and interdisciplinary field *Human-Computer Interaction* has much to contribute to the future of education. It creates and designs the ever-changing face of the machine, the *Human-Machine Interface.* This can be seen more and more physically, as interaction modalities increasingly involve the entire human body. It can also be seen mentally, as people who use a system do not only act with it for utility reasons but also interact with them in the sense that they can look behind the facade like they do with humans. Explainable AI, or rather *Transparent Technologies* in general, must be a primary goal for the designers of future

machines and tools to connect to human intelligence and to human needs. In addition to software qualities such as usefulness and usability, the plausibility, if not the logic or reasoning mechanism itself, must be transparent and questionable to support fruitful knowledge building. Interactive systems which do not provide this are potential blinders and risks, electronic parrots and tempting gateways for abuse and fraud. The interconnectivity, the accessibility, the semantics and the trustworthiness of information on large information or learning platforms can be seen as the major challenges for education in the coming decades.

The future of education in a digital world is a future of the reassessment of human knowledge, competencies and activities in philosophical, pedagogical, social, economic and technical terms. Education in the sense of building human knowledge and competencies with the help of computers is like building houses with construction machines and tools. Machine operators and craftsmen know the capabilities and limitations of their tools. They are not simply amazed and impressed by engines, steel, and power. The future is not the digital parrot or the digital human, but the intelligent, questioning and capable learner who can place the right questions into an *"Always-On Web of Culture"* and critically assimilate or reject the answers provided. Computers are just tools and their answers without explanations understandable and questionable for the asking human cannot be accepted in general, at least for educational purposes. So the future of computers in education will more than ever be about the future of human power through technology, or to paraphrase Richard Hamming:[23] *"The purpose of computing is insight, not numbers."* As a basic consequence since we actually do not know how the future will really look like, any digital support for education will be welcome as long as it does not hide its nature and contributes in a transparent way to the power of peaceful people and the goals of humanity.

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Bionote

Michael Herczeg
Institute for Multimedia and Interactive Systems (IMIS), University of Luebeck, Ratzeburger Allee 160, D-23566 Luebeck, Germany
Michael.Herczeg@uni-luebeck.de
https://orcid.org/0000-0003-4620-5186

Prof. Dr. Michael Herczeg is Professor, Founder and has been Director of IMIS at University of Lübeck. Main areas of interest are HCI in education and safety-critical systems. He was co-founder and chair of the HCI chapter of GI. He served for a large number of conferences and journals. He is an author of more than 300 publications, among them 7 books. He worked as a consultant and director for industry and government for more than 30 years.