

# The use of Generative AI in the domain of human creations – a case for co-evolution?

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## Abstract

The appearance and sudden success of generative technologies and, within this domain, Large Language Models (LLMs) have generated many open questions about the benefits and challenges of those technologies and the approaches to deal with them in the future. Put into context, we can see a new level of dialog ability and contextual understanding that is new to the interaction between the human user and the machine. This contribution uses the concept of co-evolution, originally from the biology field, to explore some of the implications of the new technologies, both on an individual and at a collective level. The perspective of co-evolution will be reflected in the application areas of Software Development and for the (higher) Education context to provide detailed insights.

## Keywords

Generative Technologies, Human Creativity, Co-evolution, Software Development, Higher Education

## 1. Introduction

Generative technologies are a type of sub-symbolic unsupervised machine learning algorithms that gained much attention recently due to their impressive abilities to act on complex and heterogeneous input data by not only processing that information to classify or interpret them, for example, but also to generate new data that is suitable for the given task. The general concept had been around for some years, initially described by Google researchers [1]. Designed initially for the domain of machine translation of texts, the so-called transformer models follow the idea of learning the context of a given text sequence in the source language and mapping that to the destination language. Since the models were trained with large amounts of training data, they became known as Large Language Models or LLMs for short. The researchers of the company OpenAI built on the initial idea. They developed their Generative Pretrained Transformers (GPT) [2], and finally, the release of their GPT3-model [3] with a chat interface brought the LLMs into the consciousness of a broad community of users. Since then, evolutions have led to the current version GPT-4 from OpenAI. Similar models were used for other data types, such as images, videos and sound [4]. In the meantime, several applications integrate the functionalities as assistance into existing tools (like search engines, e.g., Microsoft Bing or photo editing software, e.g., Adobe Firefly). More advanced applications of the approach are already appearing, such as the Vision-Language-Action-models (VLA-models), which use aggregated transformer models to chain prompts and simulate reasoning for complex robotics [5].

This contribution will focus on the socio-technical aspects of applying the technologies, subsuming them under the term Generative Artificial Intelligence (Generative-AI).

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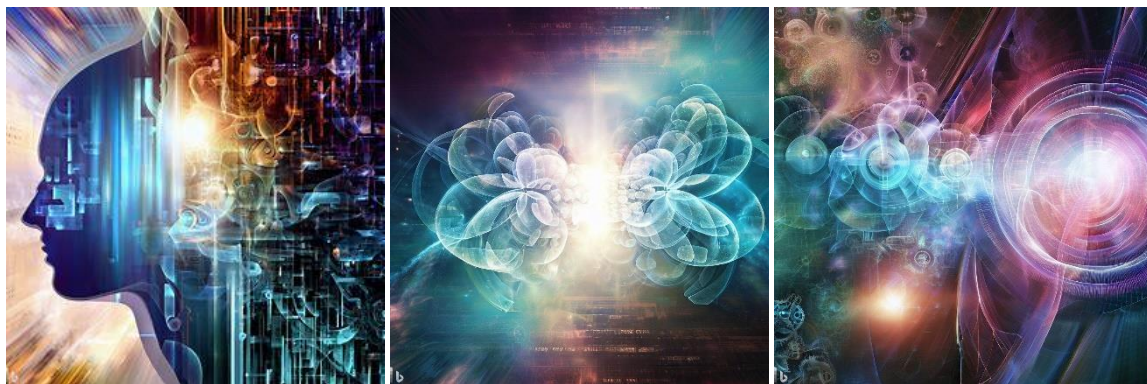
The uniqueness of the new type of software systems can be summarized in three *main qualities* that are unmatched compared to earlier ICT systems:

- 1) The ability of those software systems to *interact with the users using natural language* (called “prompts”) at a level close to how humans communicate with each other, including errors, omissions and vague expressions. While natural language interfaces have been around for some time, the level of interaction and understanding was never reached at that level, thus representing a new quality.
- 2) The ability of generative technologies to *take context into account*. The contextual processing of information is often the key to understanding the information correctly e.g. resolving homonyms and references to objects or persons in human language. While context helps to understand the natural language in general, contextual processing is also extended to the discourse with the user. That conversational context enables a discourse with a history that the machine and the human user can refer to, much like the communication between human actors.
- 3) Finally, since the systems have been trained with massive amounts of data and are extensive models, they can be used for non-trivial tasks and *produce interesting, complex and original results*. While not being perfect and sometimes erroneous (called “hallucinations”), the potential of the systems is already being demonstrated in several applications [6].

These three main qualities lead to a new type of socio-technical systems in which human users can interact with ICT in a way and at a level that can lead to impressive results in a very short time – it could be seen as an amplifier for human creative work. The technology is probably at the beginning of its development and will build more momentum soon.

Based on those observations, the research question for this contribution is how those technologies will impact the relation between the human user and the technical system both on an individual and at a collective level (sociotechnical impacts). The authors are especially interested in the impact on creative aspects of human activities, and here, the sub-question is how those impacts can be estimated. To shed some light on the relation, the concept of co-evolution, borrowed from biology, will be used to describe these sociotechnical impacts.

An illustration of the sociotechnical impacts of the current developments of Generative AI is not yet fully understood and, in the context of co-evolution, challenging to visualize convincingly. As illustrated in Figure 1 below, the use of tools using Generative AI to generate such an illustration suggests a number of images that all share the common idea of two systems or worlds interacting with each other and almost melting into something new, which might be – at the end – not a bad metaphor to start into discussing that subject further.



**Figure 1:** Some results of an experiment to create illustrations on the topic of co-evolution in the socio-technical context generated by Microsoft Bing Image Search (based on Dall-E from OpenAI) based on iterative prompting by the authors.

The rest of this positional paper is structured as follows: In the following section, the concept of co-evolution is introduced and related to the domain of generative technologies. After that, two application areas are discussed that are considered knowledge-intensive and involve a high degree of creative work: the domain of software development and the education sector. The paper concludes with a discussion and a summary also indicating the next steps in this research.

## **2. The concept of co-evolution in the domain of Generative AI**

Co-evolution [7] is a concept that initially stems from the field of Biology and describes the phenomenon in the evolution of species with a reciprocal adaptation of a population that eventually leads to a dependency between each other. A typical example of co-evolution is the relationship between plants and butterflies: Plants rely on butterflies for their replication process, and butterflies rely on (certain) plants as a (primary) food source. The positive development of the member of one species (evolution) will benefit for the members of the other species and vice versa. Over time, a mutual dependency is created that connects their evolutionary processes. The effect was called co-evolution. Another example is hermits living with calliactis, sea anemones, on their shells to provide protection (for the hermit) and a food source (for the calliactis). Different types of such a co-dependent development are known, e.g., parasitic/predative, competitive or symbiotic/mutualistic co-evolution or between species (interspecific) or also within a species (intraspecific) [8].

The phenomenon has been studied intensively in the field, and a good overview can be found in [8]. Interestingly, the concept has also been applied to other sectors, e.g., sociology, economy and computer science. A general approach to the co-evolution of humankind and machines is provided in [9], and the author elaborates on the intertwined nature in chapter 14 of the book in a similar sense as the authors of this contribution understand it. However, being written in 2020 before the advent of Generative AI in this massive sense, many of the mentioned approaches can be understood better now that some parts of that co-evolution process are unfolding.

It seems to be a universal idea that the evolution (=iterative development) of different types of systems can benefit in their development in terms of quality and development speed when they interrelate to each other – and this seems to be true in the relation of men and machines, too. Those benefits come with the price of a (possibly very strong) dependency of the two (or more) systems on each other, which could be a constraint with existential consequences. If one system (not only an individual) fails, the other system (and all its individuals) might fail too (and get extinct in the field of Biology). The fact that co-evolution appears in nature again in very different ecosystems might indicate that the advantage outweighs the drawbacks. An interesting approach in the context of book authoring was made by Chris Duffey in 2019 – before the advent of ChatGPT – in his book on superhuman innovation [10], in which he included responses of an algorithm that helped him during the research for the book as a sort of co-author. This approach made sense in some way since the author claimed that technology will massively support human abilities for innovation in the near future. Still, it seemed to be an at least unusual approach to authoring back then. Now, only a couple of years later, it does not seem strange at all and might even be a good example in terms of transparency since the author clearly distinguished between the content of the algorithm and his contributions.

In the domain of information technology, the co-evolutionary phenomenon could also be observed; examples are the Internet and the dependency of our information acquisition strategies, including sourcing (e-commerce) and retrieval services (search engines). Mobile technologies – most prominently the smartphone – have become an almost irreplaceable universal gadget of our daily lives for many activities. Navigation systems have (almost) replaced typical maps and improved our ability to orient ourselves in unknown locations using digital systems. However, on the other hand, they have harmed our (intuitive) ability to orient ourselves without them. While the advantages and the disadvantages of technology use have been widely discussed, they have rarely been put under the co-evolution scheme as a socio-technical explanation model [11].

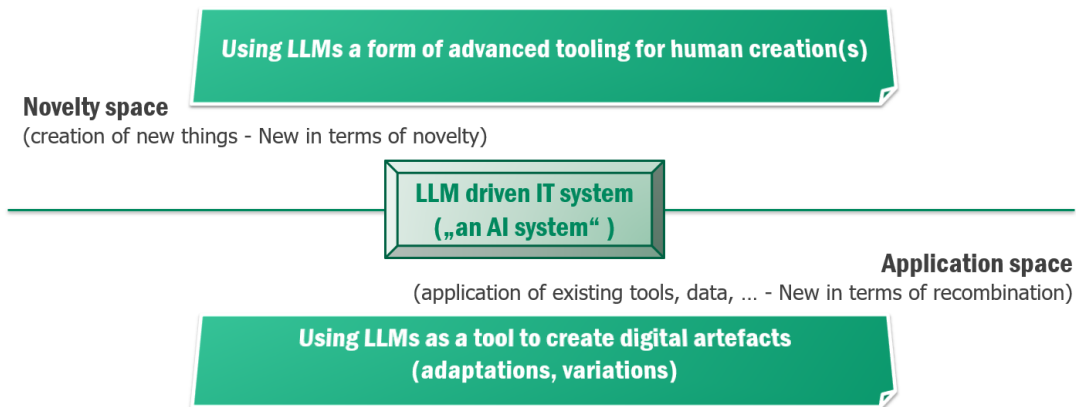
On the other hand, up to now, all of those supportive technologies have been associated with the level of assistive tooling that usually was limited to one specific domain of our lives and not at the level of advanced cognitive or creative tasks. This might differ from Generative AI due to the three mentioned general qualities mentioned in the Introduction above. Generative AI technologies are more universal and closer to human communication (language and explorative, iterative behavior, try-and-error approach). This raises the general question of the generated content or artifact type: What are *the qualities of an original creation*? Such inventive, innovative or creative power is – up to now – exclusively associated with human actors, but the borders get blurred by Generative AI and the urge for new answers. Co-evolution might help to answer some of those questions or provide explanations for developments that can be observed in the pronounced use of the technology. This contribution does not fundamentally expand or refine the co-evolution theory itself. To the best knowledge of the authors, the relation between co-evolution as a concept and the relation between the human user and the Generative-AI-system has not been pointed out by others. Therefore, the creation of awareness for that connection might be helpful and is put into the discussion with this contribution.

One of those answers could be a co-evolutionary pattern that drives evolution in both directions and creates original and creative work with a new quality:

- **From the Generative AI to the human user:** the use of already influences the creative power of the human user by quantitative means (producing results faster) and by qualitative means (producing better results, esp. in those areas in which the human user is not an expert). In this way, the use of GT can improve (or amplify) his/her creative abilities (effectively and efficiently) in a way and to an extent that, over time, might become essential for the human user, e.g., the human user loses his/her capability to be creative in a similar way without it. The looming and increasing dependency would be an indication of a co-evolution.
- **From the human user to the Generative AI:** the human might influence the learning behavior of the GT over time, esp. if the interaction becomes more individual and more local (models being built/trained for the individual user and/or application). Suppose that interaction and adaptation that comes with it persists over a longer time. In that case, the specific GT might become dependent on the user (or user community or use case) that it is interacting with, creating the opportunity to excel in the interaction with those users but also becoming dependent on those users. Once again, this would indicate the pattern of co-evolution.

## 2.1. Requirements for a co-evolution effect of Generative AI

Currently, the use of Generative AI, which has gained attraction in a massive user base, focuses on exploring and applying new functionalities in existing application areas. Following the idea of Oppermann [12], there could be a separator in the application of Generative AI into areas or spaces [13], see Figure 2 below. 1) The Application Space in which the new functionalities are mainly used to augment, replace or otherwise use the new tools for problems and use cases already known – most application areas currently explore this area. That strategy is straightforward and expected. Results are already remarkable, but the interesting results will probably evolve in another area. Development of the Generative AI system (e.g., how to interpret the context in an ongoing dialogue correctly) and the user (e.g., how to apply the functionality of a Generative AI system effectively and efficiently) can occur in the context of the situational task but is likely to stay within the boundaries of the existing application framing. These developments could be considered an evolution but is probably not so tightly coupled that it can be called a co-evolutionary development that exhibits a mutual dependency of both systems.



**Figure 2:** Separation of the action space of Generative AI solutions into the area where co-creational aspects are possible (“Novelty Space”) and the other area that focuses on the use of the technology (“Application Space”) [13]

2) The Novelty Space will use Generative AI in a way that helps to extend and expand the level of human creation in a way that was not existent/unthinkable before due to the limitations of the technology before the advent of Generative AI. This space will evolve over time and probably represent the more innovative area since it is not bound to existing use cases but new ones that emerge during space exploration.

Co-evolution is more likely to occur in the Novelty Space since the intensified and open-minded application will lead to the co-evolution of Generative AI technologies and human users over time. It is important to stress that human users need to go beyond the pure application within the existing frame of applications to preserve the creative potential and the power to create original works that are not only an imitation or recombination of existing prior work. New technology has often inspired (a new generation of) artists to express themselves or their ideas in novel ways that were not possible before. As Lee nicely puts it: *“It has never been the case that the art is created by a paintbrush, but a good paintbrush can make a big difference.”* [9].

## 2.2. Co-evolution and diversity of Generative AI

Current Generative AI systems are trained with massive amounts of data using large-scale and often specialized infrastructures. Consequently, the resulting models are large and run on centralized services of large cloud providers (such as OpenAI, Microsoft or Google). They are provided as a service (SaaS) or a platform (PaaS) that can be extended or integrated, e.g., by using APIs or providing customized services. Such a service model provides the advantages of rapid use, good scalability and ready-to-use services. However, it also has the disadvantage of a centralized provider that might lead to vendor lock-in effect and the need to use always online services.

Moreover, the centralized services use the same model for every user and every use case. Learning and adaptation are only achieved based on the prompts and responses as contextual information within the user session.

From a sociotechnical perspective, such an application model could drive toward centralized and monopolized infrastructures that might also lead to difficult situations as a critical mass of power could be focused on a single application/technology or organization. Co-evolution in this situation would only move into one or a few directions, which limits its evolutionary power – in the field of Biology, this would represent a monoculture known to weaken an eco-system and are less resilient against change or negative influences. As a result, the diversity of such a world of centralized Generative AI systems would be low and the evolutionary potential limited.

A world with a limited number of models managed, controlled and owned by a few organizations could also be a problem, especially if the human society cannot obtain any control over them (e.g., for the case of publicly owned organizations). Too little diversity in the models

leads to a monopoly of Generative AI that might cause social problems, e.g., if access to the technology is limited and thus the creative potential of some humans is significantly lowered – they are exempt from the benefits of a co-evolutionary development.

If, on the other hand, the technology scales down in terms of resources needed to train and run Generative AI systems (locally), the result would be a higher number of systems, that will be different with respect to the model and the use case. The world of Generative AI has become more diverse. It could explore more paths of evolution and co-evolution with the different user groups: *decentralized models lead to a more diverse ecosystem of Generative AI systems.*

Moreover, the user would gain control over the use of ‘their’ generative AI model, e.g., they could decide when and how long to use it. The lifecycle of the model is determined by the user and not by the provider, which becomes more important if the model is more contextualized than a central model and if it has a longer lifecycle in which it can accumulate more input data that improves the model over time: *decentralized Generative AI systems can be more personal, and its lifecycle is under the control of their owners.*

In a way, *decentralization of Generative AI can be understood as a democratization of the technology* that is beneficial for society in the long term as it lowers the danger of power misuse of centralized solutions while opening up for the full potential of a co-evolutionary development. First movements towards that direction can be seen already with the Llama and the LLama2 model of Meta [14] and the genuinely open models such as the initiative EleutherAI [15] and approaches that make it easier to run LMMs locally, such as GPT4All [16]. Although they cannot compete with commercial counterparts, they also exhibit a fast development pace with significant improvements in short cycles.

### **2.3. Social impacts of co-evolutionary Generative AI**

Generative AI, in its current development speed and user adoption, is likely to initiate a co-evolutionary pattern that will have an impact on both the technology and the human users – individually but also at a collective level. Thus, it is likely that there will be social impacts soon which are not predictable due to their disruptive nature. It might be useful to look back into the history of technology development to anticipate some of the societal reactions that are likely to occur or already occurring.

One illustrating example was the machine-breaking movements during the Industrial Revolution in the 19th century when the appearance of mechanical waving looms represented a danger to the existing craft of hand looming, endangering the work and economic existence of many people in that industry by the time. The so-called Luddites were destroying the (new) technology – the mechanical looms and the factories – to fight the technology’s societal impacts (e.g. lost job opportunities, lower wages, lost opportunities for skilled workers). History tells us that the resistance of the Luddites did not succeed in the long term and that the negative effects of the introduction of the new technology were outweighed by the advantages of that technology (e.g., new jobs created, lowered prices that made products affordable for a larger group of customers).

Furthermore, while the historical example happened long in the past, the general role of a Luddite remains alive in our times at an individual level, at a group level and even at the level of a society. Today, skepticism and inactivity against the (possible) impacts of Generative AI are also creating a danger that investable developments will be recognized too late and possibly addressed in the wrong direction – against the technology and not against the social impacts that come with it.

Proper redemption will be the most appropriate way to deal with it, as the technology available to humankind will always be used if it seems beneficial (at least from some). With that respect, it is also useful to revisit the critical remarks of Joseph Weizenbaum in [17], where he points out the differences between computer technologies and human intelligence and although many of his claims and raised questions date back some time ago, they are (again) very relevant in the context of the technologies in question.

The advent of Generative AI lets us enter an age in which, again, a certain amount of assumptions, routines and skills are challenged; this time not on the level of mechanical skills but on the more advanced level of cognitive skills that we consider to be exclusively human – until now. With the understanding of a co-evolutionary development, we should look for ways that help humankind evolve with the technology in a way that represents progress (in increasing our abilities) and that offers redemption for the negative social impacts that occur in the transition phase in the best way possible.

### **3. Application of the concept**

After introducing the concept of co-evolution in the context of Generative AI, this section explores the theory with a reflection in two distinct application areas: first in software development and second in education, more specifically, the Higher Education sector. These sectors have been chosen because they are distinctive in their perception of the originality and creativity of the results they create: in both cases, it requires highly skilled human individuals to create the outcome, the environment that they operate in is complex and dynamically changing, and it is highly contextualized – different iterations seem to be similar from a more general point of view but are very different when investigated more closely.

#### **3.1. The domain of Software Development**

Software development can be a very challenging field, even for proficient developers. Working as a developer means finding creative solutions every day because every problem a developer faces can be utterly different from those he or she has worked on before. Therefore, software development is not only about writing code and working with programming languages and control structures but more about “translating” existing real-life processes to a data model and the associated business logic.

What makes the software development sector in the context of Generative AI so interesting is that software development has always been a professional sector that has driven and implemented digitalization. However, due to the need for highly creative work, it was less affected by digitization than other sectors. Generative AI gained much popularity, especially in the last few months, because of the release of ChatGPT. Therefore, software development must undergo extensive change because it is now a target of the digitalization transformation process for the first time. The hype about Generative AI in software development started with the release of ChatGPT. ChatGPT creates code snippets based on user input in natural language and completes existing unfinished code snippets. Besides ChatGPT, there are also many other Generative AI tools for developers. According to a recent paper by Ebert & Louridas, the most relevant tools currently are ChatGPT, CoPilot, Tabnine, and Hugging Face [18]. This paper focuses on CoPilot from GitHub because it has the most recent research and is the most convenient tool to integrate into the developer’s workflow.

CoPilot is available as an extension for various development tools like Visual Studio Code, Visual Studio, Neovim, and the JetBrains suite of integrated development environments (IDEs). CoPilot is developed by GitHub, Microsoft, and OpenAI and has been trained on code from sources open to the public, including source code in public repositories, which has been published on GitHub. CoPilot works by providing suggestions for code auto-completion based on the existing code. Developers can use those suggestions easily [19]. To reach the point where co-evolution can be possible, developers must integrate provided generative AI tools, such as CoPilot or ChatGPT, in their workflows. Therefore, the most essential aspect is the acceptance of Generative AI since it has the potential of a *transformative change of existing working habits* for the sector of software development. Russo investigated how the acceptance of Generative AI in software development can be ensured. He developed the Human-AI Collaboration and Adaptation Framework (HACAF) based on his mixed-methodology investigation. Even though developers see

advantages in using various Generative AI tools, seamless integration into existing workflows is sometimes the most substantial aspect of accepting these tools. [24]

Provided that those Generative AI tools are integrated, the next step would be focusing on how a potential co-evolution of software developers and Generative AI could look. Recent research shows how software developers interact with CoPilot during development. For this research, the authors of [20] recruited 20 programmers and investigated how the programmers interact with GitHub Copilot. Barke, James & Polikarpova recommend how the CoPilot should evolve to best integrate into the workflow of the developer [20]. Among other things, it was revealed that there are two different modes of interaction: *acceleration mode* and *exploration mode*. Acceleration mode means when the developer has a concrete idea of what he or she wants to write next. CoPilot helps to be more efficient and faster by completing the code based on function names or comments in natural language. When programmers still need to become proficient in a programming language or are unsure how to solve a problem, CoPilot is used in the so-called exploration mode. In this mode, CoPilot does not act as a programming assistant but as a partner who supports developers in finding solutions [20].

The co-evolution pattern, which is the focus of this research, would only occur in exploration mode because, referring to Figure 2 in section 2.1., acceleration mode would be positioned in the so-called "Application space". Only the exploration mode has the potential to reach the "Novelty space", even if the tool has yet to reach that point.

However, before focusing on co-evolution in collaboration of humans and Generative AI, initial steps need to be taken to familiarize the human users and gain experience with this new form of interaction. There are undoubtedly many things a machine or, in this case, Generative AI tools can do better than humans. Machines being able to work with large amounts of data is a fact people need to accept. The essential contribution humans have to collaboration between software developers and Generative AI will be investigated in future research by the authors. Until now, there is only research about what potential Generative AI could have in the software development sector. According to Ebert & Louridas, Generative AI in software development can increase productivity by supporting developers during their creative processes and solving problems where complex algorithms need to be implemented. Furthermore, it can be used for writing summaries about interviews, meetings, reviews or documentation. [17]

Even if there is no empirical research evidence about the nature of irreplaceable human skills for the software development process yet, the fear that Generative AI would replace software developers entirely seems unnecessary. Nevertheless, the field of software development is going to change significantly. Welsh even writes in a recent paper, "Programming will be obsolete." He is convinced that programming, the way people do it today, will be utterly irrelevant 20 years from now. He describes that basic programming concepts, such as programming sorting algorithms, will be irrelevant. He compares that to developments experienced in the past; for example, today's software developers do not need to understand the functionality of a CPU. Future software developers probably do not need to understand how complex algorithms work. [21]

In conclusion, Generative AI will allow software developers to focus on more abstract and complex subjects like software architecture. At the same time, repetitive tasks like the configuring of standard code blocks ("boilerplate code") or automated testing can be done by Generative AI. Suppose using those tools becomes a daily routine for the software developers and an ordinary tool in their toolbox. The authors believe that more advanced working practices will unfold that show a co-evolutionary pattern.

If the skillset of software developers is going to change, education in the software development sector will also change. Educating software developers is also an auspicious sector that needs to evolve because of tools like ChatGPT. However, not only education in software development will change, but significantly Higher Education will change a lot. This topic will be focused in the next section.



### 3.2. The domain of (Higher) Education

Edward Lee raises the question, “What should we teach the young?” ([9] p.309), and this becomes an even more prominent question in the rise of Generative AI. He argues that men, unlike machines, have always learned everything from scratch and that the transfer is much more difficult than with machines, where data can be copied without loss or complicated learning processes. Nevertheless, maybe this process of (re)-constructing the realities from generation to generation is also a form of interaction between the generations that enables us to think and experience knowledge and wisdom in new ways – again and again. Lee has a point when he mentions that wisdom and the question of the how and why might take a back seat in favor of skills and knowledge in current education, but Generative AI might force us to think differently in this respect. It might become less important to have (all the) knowledge and be able to excel at (all the) skills that might be relevant because those can be supported (or replaced?) by the application of Generative AI.

Instead, it becomes more important to have a good understanding of the technology’s inner workings, the effects, the effects that it causes for us at the individual and at the collective level and the goals we are reaching for. This should be a educational goal for the engineering and Computer Science subjects in order to prepare the next generations for a profound understanding of the technology to ensure a) the correct function of existing and developing systems and b) to lay the foundation to the further development of the technology. All other subjects should be taught to develop a reflected and critical position to the application of Generative AI to develop an individual and independent position in which technology remains a supportive tool and not a tool that the user ultimately depends on. That would enable us to estimate the potential and the limitations of the use of Generative AI technologies – leading to *more informed decisions and actions* than just to use the technology as it is without further questioning.

Providing that ability will become a cornerstone of education programs in Higher Education, probably with variations on the depth level depending on the different subjects. Similar to the distinction in the adoption and use of digital technologies in general between the group of Digital Natives and Digital Immigrants [22],[23],[24], two different fields of education paths can be identified:

- **Skill up the existing generations** to make them fit for a future in which generative AI will be a part of everyday life and the working environment. Here, it will be important to connect the existing knowledge and experience that the learners have acquired over their lifetime in the different paths they took in education and during their professional activities. Consequently, this part not only focuses on teaching the teaching of the technology insights but also addresses the needed change(s) to existing practices and the adoption of new practices and ways of thinking. This inertia in technology adoption is not new or specific to Generative AI but probably will play an important role because the application is not limited to a few specific use cases but will be rather broad and iterative but expanding. In that sense, it might be compared to adopting the Internet, which started as a particular piece of infrastructure that became a common and general tool for everyone over several decades and with substantial sociotechnical implications. While adopting Generative AI might not take that long, the sociotechnical effects might not be less prominent and thus affect the world significantly.  
If addressed correctly, it could lead to the situation that the new technology can be seen as a chance rather than a danger, which will help with the technology adoption.
- **Educating future generations** with the skills that will be needed in the future of Generative AI. Besides the education about the inner workings of the technology to create transparency for learners, it will also be important to focus on tasks that are automated or heavily supported by Generative AI to prevent an ultimate dependency on the technology. Following the classic example that using calculators will not replace mathematical understanding, this will also address other skills like writing essays,

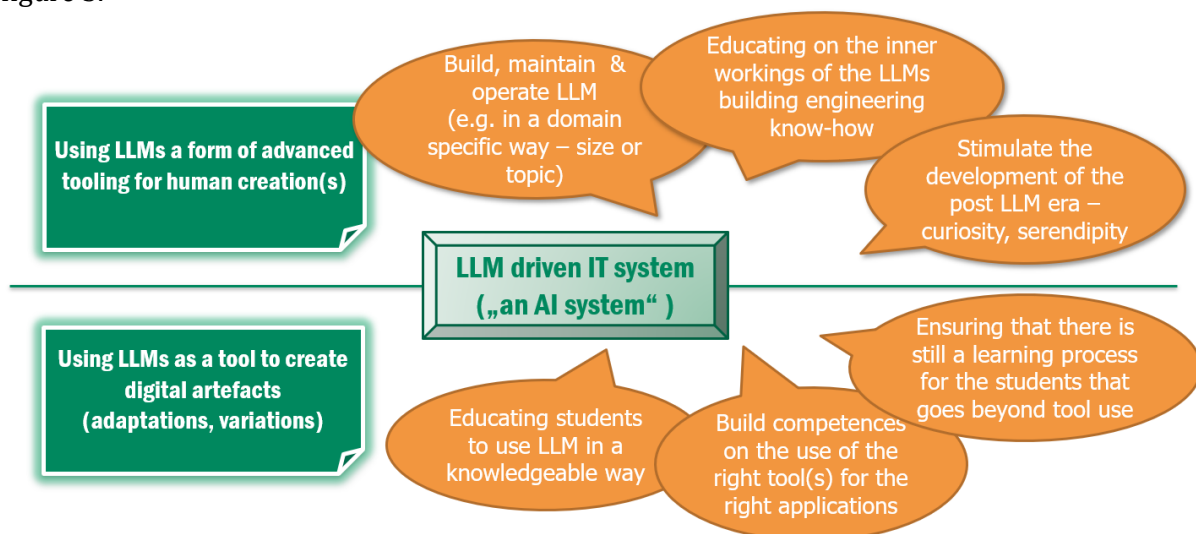
preparing presentation materials or doing information research. While tools and technologies will support those activities, among others, in a substantial way, it remains important that learners possess the core elements of those skills in order to remain independent from the technology and develop *good judging capabilities* in order to distinguish good from bad results – in a similar way like mathematical skills help to quickly estimate the results of calculations in order to spot major mistakes.

This field will also relate to shaping education and the educational system itself. With the advent of Generative AI as support tool, assessment methods need to be revised, and it becomes apparent that problem-based learning and proving the applicability of a certain competence gains importance over pure knowledge acquisition and knowledge testing in exams.

The extensive survey by Zang et al. [4] also investigates the (higher) education field. It asserts high potential that could “...revolutionize education by improving quality and accessibility of educational content, increasing student engagement and retention, and providing personalized support for learners.” [4]. It is interesting to note that several dimensions are affected by the content creation/improvement at the side of the lecturer and the side of the learner as the most prominent example. However, the education process aspect is also mentioned by providing a higher level of automatization (e.g., with chat-based feedback). At the same time, a higher level of individualization can be reached. This would improve the scalability of the overall process by freeing time for the valuable direct and personal interaction of the lecturer and the student on more advanced or tricky parts of the educational content that require an intense dialogue to be mastered.

The study of Nah et al. collected several challenges that come with the use of Generative AI, such as “...harmful or inappropriate content, bias, over-reliance, misuse, privacy and security, and the widening of the digital divide.” [6]. From the perspective of educational use, over-reliance is probably one of the severe dangers for the learning process. It often occurs slowly and unnoticed but damages the learning process significantly. The tool use might even create the perception in the learner to have a better understanding of a topic, which could be accompanied faster than by ordinary means. However, it might be only at a superficial level of understanding if not being practiced, e.g., by problem-based learning approaches.

Applying the model with the separate usage spaces for the Generative AI technologies introduced in section 2.1, a number of activities can be identified in the education domain, see figure 3.



**Figure 3:** Using the model of the two different spaces in the realm of Generative AI (“Novelty space”, “Application space”) to position a examples of educational activities in the different areas. [13]

From the application perspective (“Application space”), the most obvious and foremost example is the education of the students to use the tools that use Generative AI competently and knowledgeably, appropriate for the individual domain, which leads over the different courses to a toolbox for the students and a grown knowledge (and experience) which tools & technologies to use for which application.

Although incorporating those new tooling in the educational process, it will be the responsibility of the Higher Education Institution (HEI) to balance the tool use in such a way that the learning process for the specific subject remains intact and goes deeper than learning to use the tool(s) only. This area is expected to involve the adaptation of didactic methods and materials and iterative experimentation of which usages are effective and which are not.

The co-evolutionary effects determine the other space (“Novelty space. It allows the students to explore the inner workings of Generative AI at an advanced application or technology level. Here, the foremost goal would be to develop engineering skills for working with Generative AI by learning to use and adapt the technology and possibly also the models, given that they are small and accessible enough to allow experimentation with the limited resources of an HEI. Over the long run, it should be the intention of the HEI to stimulate curiosity and serendipity within the students to develop and evolve the technologies further – either in terms of technology development or in terms of application areas. This could drive the co-evolutionary process between the technology and the student’s learning process within the HEI.

#### **4. Discussion & Conclusion**

This contribution evaluated the well-known concept of co-evolution, originally coming from the field of Biology, in the context of the current rapid technology of Generative AI that reached its breakthrough by combining Large Language Model with Natural Language Interfaces in the style of a chatting application (e.g., ChatGPT). While not being limited to that application area, the authors have pointed out that Generative AI is not (only) yet another assistive technology, but one that might help users to develop their skills and knowledge to new levels and to improve the technology while interacting with the technology – they co-evolve in the process. While this might not happen with every application of Generative AI, the authors anticipate that potential in areas in which the use of technology leads to novel and original creations (called the Novelty Space). Conditions and implications of co-evolutional patterns have been sketched in the contribution, and the reflection on two application areas showed the potential of the co-evolutionary pattern using the technology.

It is certainly discussable whether framing human users and Generative AI systems as co-evolving is an appropriate metaphor. However, the author’s position is that the awareness of the concept of co-evolution might help to gain insights into the nature of the interaction and the adaptive development of both systems. It might contribute to developing an explanation model about the nature of the relationship and trajectories of change over time. The authors hope to propose co-evolution as a new way to analyze sociotechnical phenomena to draw useful methodological and theoretical exchanges, which becomes more important now as the generative technologies provide a new quality of the dialogue between man and machine that will open an even more interesting field of research.

This contribution aims to give an impulse to think if co-evolution is an appropriate pattern for the collaboration of humans and Generative AI. The goal is to highlight the potential of Generative AI in two exemplary sectors. Developing software and learning (especially in Higher Education) are highly creative and cognitive processes where people craft something. While in software development, the result is a working program, the result in the learning process is implicit. The authors consider and pose the question of whether the use of Generative AI is changing not only the results of the mentioned processes but also the result-creating process. Could the use of Generative AI in the software development and Higher Education sector lead to irreversible process changes? Is it possible that developing software and learning will be only possible

efficiently or effectively with collaboration with Generative AI? This contribution and the presented concepts are not fundamentally new. However, the authors would like to present this assumption and concepts with this contribution to encourage more research on the relationship between humankind and Generative AI.

Due to the novelty of Generative AI and the current breakthroughs, many of the effects can only be anticipated in the future. Empirical research will be needed to reflect on the conceptual work of this contribution. This will be subject to future research by the authors. Still, using an established pattern might help shed some light on the observable effects that become visible in the following months and years to come – something that we might call the age of Generative AI when looking back to these days from the future.

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