AI X sustainability 2035 – innovation dynamics, transformations & challenges to fashion management and education

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ABSTRACT

We are at a crossroads when it comes to Artificial intelligence-based innovations being used in the fashion industry. In this paper, a glimpse on new rules of the innovation game, and sustainable development in design, supply chain management and fashion consumption till the year 2035 is presented based on an anticipative, causal-layered analysis.

To stimulate discussions on pedagogies and ethics, it will be put to discussion that more industry-specific AI solutions be fueled by collecting, aggregating, analyzing and using and monetizing data connected to all forms of value creation activities in fashion. In the adoption of AI in and for fashion especially embedding vectorization as a form of data aggregation and collection will change many rules of the innovation game in fashion design, retail and marketing, styling and fashion reception as well as fashion consumption. Other forms of data aggregation like the emergence of to a greater or lesser extent comprising digital product passports will change the rules of the innovation game in supply and production. More new sets of data on textile properties and integrating knowledge both on fibers and textiles as well as on fashion consumers' preferences will be integrated. However, since the data collection, aggregation, analysis, use and monetization activities of major fashion players are governed by existing market logics of very competitive mixes of price, brand and quality, the future funnels of AI progress are widely open. Existing blind spots and biases in data collection and aggregation pose ethical questions in abundance. Based on availability, automation and bandwagon biases and existing logics, it is probable, that AI tweaks for optimization of aspects of value-creation activities along todays' performance standards will lead to the fashion industry doing more of the same but just much faster than today.

Keywords: AI, anticipation, biases, embedding vectorization, fashion consumption, fashion futures, innovation

INTRODUCTION

At the beginning of the year 2025 AI solutions are increasingly tweaked for optimising all kinds of value-creation activities in fashion. AI solutions as a form of general and multi-purpose technology are progressing at tremendous pace also given the enormous capital investments with Global AI funding increasing 59% QoQ to $23.2B in Q2'24 — the highest quarterly level on record, exceeding even the level seen during 2021's venture boom. The jump was driven by a handful of $1B+ rounds and outpaced the growth in broader venture funding (+8%). Meanwhile, AI deal count climbed by 16% QoQ to reach 948, bucking the trend in venture deals more broadly (-7% QoQ) (CB Insights 2024). In the fashion industry especially larger players from different segments are investing heavily in AI applications to change their fashion design activities, their supply chains – also to comply with regulations—foremostly their marketing with massive investments in generative AI, as well as their styling and fashion media activities triggering changes to fashion consumption practices. Futures are formed by adopting AI applications. High time to shed a light on probable developments, anticipate and speculate on the intersection of AI in fashion in 10 years and to scrutinize which effects the adoption and the scaling of AI uptake in fashion has on sustainability.

LITERATURE REVIEW

Although there are manyfold reports, industry voices and also academic contributions speculating about the future of digital fashion, the impact on artificial intelligence based solutions on the certain parts of value-creation activities in fashion, most articles do not provide a thorough comprising anticipative analysis based on a conceptual model for understanding AI in its development as a multi-purpose technology with tweaks for different industries. Most articles and discussion are oriented on certain parts of the fashion value-creation cycle with discussions on the impacts of AI on fashion design, production of garments and apparel, the supply activities and supply chain management, marketing and retail, fashion styling and reception as well as fashion practices. Only very few articles have been provided so far a conceptual lens for understanding the development of AI technologies in a more fathomable way. Most contributions are either very technical and disciplinary oriented when it comes to reviews of the state-of-the-art of artificial intelligence methodologies, foundational, models, AI tech stacks and now AI agentization.

In addition, the standing body of literature and especially reports and contributions by providers of AI applications and solutions only cover the positive effects of adopting AI applications in and for optimising value-creation activities. In most reports, the undeniable positive effects of optimising fibre and material choice – also on the basis of better product environmental footprint assessments, the positive effects on designing along the lines of the 9Rs of the ladder of circularity (Minguez, Erlantz & de

Camara 2021)), the positive effects of optimising prototyping, of optimising supply chains, of better marketing and of diminishing returns with optimising excess production are being mentioned.

Although there is a growing interest in the environmental impact of AI as a general purpose technology with pointing to the overly negative direct and indirect impacts of AI applications and the consumption of resources such as water, energy and other raw materials, indicating both that data centres, cryptocurrencies and AI consumed almost 2 per cent of total global electricity demand in 2022 and these figures could double by 2026, that AI systems take a heavy toll in training models and that AI applications can consume significant volumes of water, either directly, for cooling towers, or indirectly, through water use for electricity generation. Some predict that by 2027, the total water consumption of all AI systems may exceed 0.38–0.60 billion cubic metres, roughly 200,000 Olympic-sized swimming pools. (WTO 2024: 16), the scrutiny of direct negative impacts of AI in the fashion industry in still in its infancy.

Given the tremendous pace of progress in AI fields, with huge capital investments (CB Insights 2024), patenting activities (compare WIPO 2024) and monetization and trade in intellectual assets (compare WTO 2024), it seems appropriate to provide a more integrating and also more robust perspective to be able to infer future lines of developments and to scrutinize the question if and to which extent the future developments and adoption of AI technologies tweaked to optimise fashion design, supply, production, marketing, retail and fashion styling and reception as well as practices in fashion media and fashion consumption practices will also fuel more sustainable development.

METHODOLOGY

To scrutinize the research question in how far the further progress and adoption of AI technologies may lead to more sustainable development in and for the fashion industry, this paper uses an integrated anticipative analysis, which combines the notions of anticipation, foresight and different futures methods (for an overview of anticipative practices compare Poli 2024).

A mix of cross-sectional analysis comprising different realms and arenas of value - creation in fashion – also sorting out which sectors have been and will be more prone to adopting AI – which sectors will go from experimentation to full throttle application – with employing a scan data approach built on STEEP future methodology has been used (For the STEEP future methodology compare Hichert, Schultz 2024: 355).

A longitudinal analysis along the lines of a causal layered analysis (building on the bibliometric analysis of Wahab 2024) identifying events, patterns, structures and

myths/narratives and founding logics of AI development and adoption for the last 10 years and the next 10 years has been employed.

Archival research together with secondary analyses of papers, reports and opinion pieces as well as interviews with leading figures in AI and fashion tech & AI, grounded theory and case studies form the background of this multi-method qualitative, abductive undertaking creating new hypotheses for forming futures and how to form futures – an interpretivist and pragmatic approach (for the delineation of the pragmatic approach compare Mische 2022)

Conceptual lens for charting progress in AI in and for the fashion industry along the lines of sustainable development

The analysis builds on conceptualising AI as a general and multi-purpose technology, which enables actors with creation value-creation in different arenas of value-creation along the lines of the the DIKW Hierarchy (Rowley (2007); Nguyen, Paczos (2020)). Differentiating between data, information, knowledge and wisdom along the lines of sophistication and epistemic complexity is utterly necessary when working with AI, because most AI technologies, models and applications are based on certain inputs of data, which then get aggregated to information, more valorized with producing knowledge ("how to") and creating wisdom ("why, when, to which degree to use which knowledge").

Of fundamental importance of understanding robust lines of development of AI and algorithmic innovation is the scrutiny of value-creation activities around data the data life and valorisation cycle, including the activities of data collection, data aggregation, data analysis and data use and monetization.

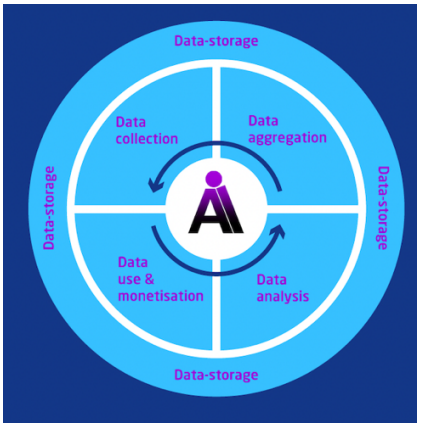

Illustration 1: Activities in the data valorisation life cycle. Own illustration based on Casalini, F. and J. López González (2019-01-23), "Trade and Cross-Border Data Flows", OECD Trade Policy Papers, No. 220, OECD Publishing, Paris. http://dx.doi.org/10.1787/b2023a47-en

Illustration 2: Conceptual lens for charting avenues of progress for AI in its progress and adoption in and for the fashion industry. Own illustration

With this conceptual lens the analysis of forming futures of different actors by developing further and using more thoroughly AI for optimising or creatively altering sometimes even destroying value-creation activities in fashion goes from being centred on AI applications to scrutinizing if and to what extent and which quality and validity new data are being collected.

Furthermore it is being scrutinized how data is aggregated e.g in establishing new data quality standards, or defining to a greater and lesser extent digital product passports or blockchain solutions. To understand and integrate the progress of AI foundational models, operating models and agents the underlying activity of analysing and recompiling data is important. For a discussion especially of future avenues of AI X sustainability it is also of utter importance to scrutinize the practices of data use and the monetization of data. The questions which data are really used and in how far new intangible assets are being created is highly relevant for discussing more contributions to sustainable development.

As regard the intersection of AI and sustainability in this perspective, the United Nations Sustainable Development Goals (SDGs) and the indicators specified for the 17 SDGs (United Nations 2024) are used to be able to estimate impacts of data-and AI-enablement and empowerment.

RESULTS AND DISCUSSIONS

With applying this conceptual lens on the use of data and artificial intelligence at the beginning of the year 2025, there is a cross-roads: Many actors are still into finding their way sometimes very different ways to dive deeper into data collection, data

aggregation, data analysis and use –also and foremostly with the help of more and more sophisticated more fashion industry specific AI applications. They are into turning either on an avenue with more subtle and more sustainable development goal-oriented collection, aggregation, analysis and use of data on apparel, fashion and conscious consumers.

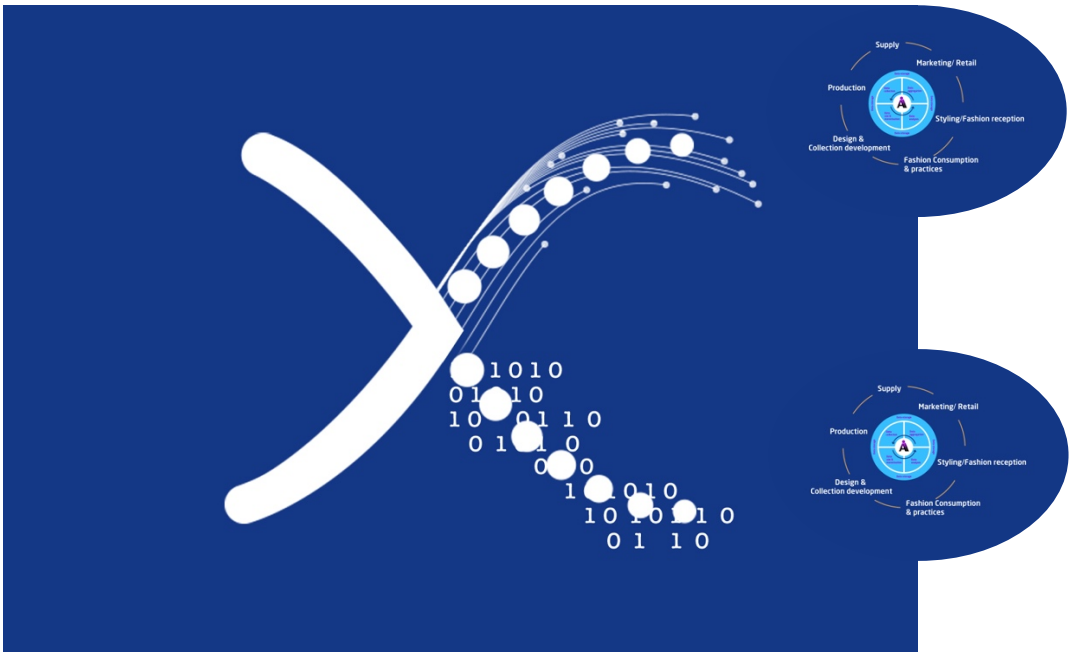

Illustration 3: The crossroads into the future with 2 avenues of data and AI empowerment. Own illustration together with Hanieh Zadszar

AI X sustainability in 2035 – avenue 1- Amelioration with data and AI-powered progress

On the one hand more collection of sustainability relevant data is under way, the aggregation of data in digital product passports is also happening and the use of data and knowledge of different fashion players especially for producing more sustainably is under way, with some companies being able to for example lower their emissions per single product. Some players are even possible to begin monetizing their excellence in production and supply chain management in selling advisory services or gaining a competitive edge with being regarded as more sustainable and responsible by their more conscious clients, who are sometimes willing to pay a premium for more sustainable apparel. This is the upper leg of the X and a possible way into the future.

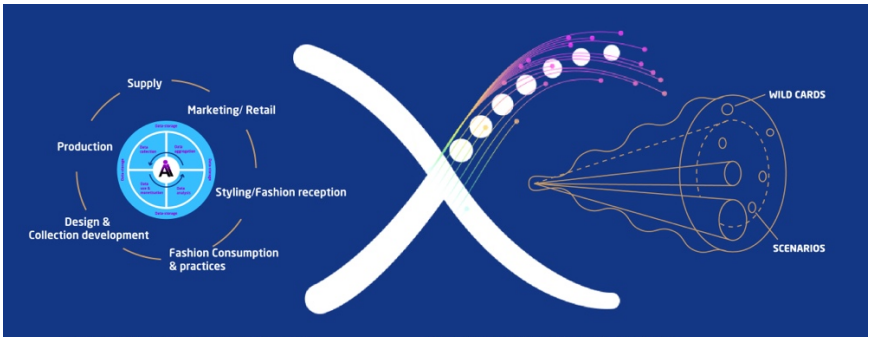

Illustration 4: AI X sustainability in 2035 – avenue 1- Amelioration with data and AI-powered progress. Own illustration together with Hanieh Zadszar

In this avenue an amelioration and tremendous progress, is made with data and AI powered progress along the lines of the SDGs Amelioration with data and AI-powered progress That is to say, fashion industry value creation activities will not only do faster, better, but will do completely different products on the basis of totally altered data sets will be offered and sold and used differently. New sustainable qualities will be established.

AI bears great potentials to automate tasks, amplify and accelerate existing fashion output and sale and ameliorate the fashion products to become more circular and regenerative textile solutions with extended life-cycles and differentiated sustainable qualities in the future. AI and the thorough responsible collection, design and aggregation, analysis, use and monetisation of data will enable the fashion industry to move from doing more of the same, faster to creating totally different, better, more customized, more sustainable, quality-differentiated, more flawless textile solutions, which are more customized for clients and better for the planet. This leads to tremendous progress on the SDGs.

More subtle data design and collection and AI's use for fashion production especially with improvements to textile production and textile processing holds large benefits for improving water quality (SDG 6.3), water-use (SDG 6.4) and water resources

management at all levels (SDG 6.5), thus also significantly reducing marine pollution (SDG 14.1).

AI and the collection, analysis and sharing of data on textile, their processing and best practices will also help to develop more environmentally sound management of chemicals and all wastes (SDG 12.4) with more sustainable practices and more innovation-enabling reporting along Digital Product Passports (SDG) 12.8).

Increased use of AI on better data has the potential to promote inclusive and sustainable industrialization (SDG 9.2), upgrade infrastructure and retrofit industries (SDG 9.4), promoting the development, transfer, dissemination and diffusion of environmentally sound technologies and practices (SDG 17.7).

The increased use of data can also help to create better awareness (SDG 13.3) education and upskilling initiatives for sustainable production, development and sustainable lifestyles (SDG 4.7) and thus achieving higher levels of economic productivity through diversification, technological upgrading and innovation (SDG 8.2).

In the next ten years, with fashion actors taking the avenue of amelioration, the fashion industry may look totally different than at the beginning of 2025. By speculating on the future and anticipating certain parts on the basis of underlying causal layered analysis and the ongoing secondary analysis of reports, press releases and other contributions to stimulate discussion on how to form futures, the following aspects might be relevant.

Illustration 5: Avenue 1 AI X sustainability 2035 – Sustainably „ameliorated“ fashion industry in 2035. most important facets of a changed industry. Own illustration.

Taking a look at the cycle of nested value-creation activities in 2035, AI as a fundamental part of changes to the collection, aggregation, analysis and use and monetization of data could lead to changes to the value-creation activities.

Changes in and for Design and collection development

Appreciated/Augmented choice of preferred materials with information and knowledge about circularity & regeneratively of materials. Materials, which are more sustainable, more regenerative and recyclable would be appreciated already in the list of appreciated and not preferred and banned materials. Based on collecting and aggregating thoroughly more data on the functional and sustainable quality of materials the choice for designers between materials will also be augmented. With the help of AI designers will simply know more and know better, which materials to choose.

Augmented pre-fit means more generative & regenerative design based on capsules/customer data repositories. Generative AI will especially be used in conjunction with 3d scanning data to provide better fits of apparel, thus reducing returns.

Anthropomorphically better informed design decisions based on better data collection, aggregation and analysis. More fashion companies can go into customization and personalization and beyond confection sizes based on customer data repositories.

Changes to production

As for Production more rapid-radical prototyping, mass customized, virtual/real, made-to-measure/ on demand fashion may be enabled.

Appreciated/AIsseitifed – Especially for production new Digital/AI assets will emerge with the forms of using embedding vectorization. The tech packs of today will be the assets of apparel in the future and based on this more thorough and sophisticated data valorization and lifecycles, there will also be tremendous changes to intellectual property rights (which can also be seen already in 2025 compare WIPO 2024 and WTO 2024). Especially within the increasing relevance of the combination of financial & sustainable materiality based on changes to the international Financial Reporting Standard in the aftermath of the year 2023, more circular & regenerative design & production will be getting a more attractive choice for companies.

Changes to supply management

In supply management more advanced and informed, sustainable & regenerative product data management and sustainability-oriented Product Lifecycle Management solutions will enable the establishment of more customer/life-cycle oriented management and also prolonged lifecycles with integrating resale as an integrative

part based on more subtle data-collection based insights on the profitability even after the first sale of clothing.

The cornerstones of these developments is on the one hand the better and also open-innovation and data-sharing oriented establishments of eco-systemically integrated platforms for data exchange and production. Several players have been embarking together with subtle data- and profit-sharing approaches into pooling their resources for better production and supply chain management. On the other hand, major players will also establish digital product passports including more relevant data covering longer life spans of and for apparel. The fashion products will be more authenticated and traceable.

Changes to retail and marketing

In marketing the landscape will change to more actors moving to more informed, evidence-based advertising based on better product catalogs based on digital product passports also in reaction to increasing compliance requirements

In retail, More reactive, nudge-oriented omni-channel customer and shopper journeys will be established integrating AI solutions and agents vendor and fashion-company as well as customer-side oriented. More subtle forms of conversational commerce and bots will be established using tremendous progress in multimodal AI, and natural language processing and understanding.

Based on more thorough data collection and automated analysis of data more algorithmic/AI-enabled, frequently very dynamic pricing might be established also combined with forms of more appreciative-adaptive retail (automation). Adaptive in this sense means that e.g. store assistants will be integrated with their own AI gent solutions in more encompassing and entrenched customer journeys.

Changes to styling, fashion reception and fashion media

More AI-accentuated styling based on automated processing of manyfold social media crawling combined with more real-AI-timed posts/trends. Especially the combination of AI and augmented reality solutions, also on the basis of new wearables will probably provide more augmented socially and sustainably extended reality solutions used for (personal) styling and new forms of fashion journalism and fashion experience (also virtual)

Changes to fashion consumption and clothing practices

With the integration of AI in mobile phones which will start in the beginning of 2025 with Open AI being integrated in the apple ecosystem, slowly but surely fashion consumption will be annotated on basis of existing customer needs and habits. There will be more AI-activating, more co-creation – based on AI agents available on mobiles with new interfaces. Consumers will be more assisted – with digital sustainable nudging based on more sustainable/regenerative smart choices and ai agents.

Consumers especially those consuming pre-loved products will be empowered with more AI powered anti-counterfeiting. Increasingly brands will be more AI-experimenting. They will test virtual fitting, pre-testing informing design and new product development also integrating customers more into co-creation also based on generative AI.

AI X sustainability in 2035 – avenue 2- algorithmically intensified, hyper-pitched and hyper-paced fashion industry.

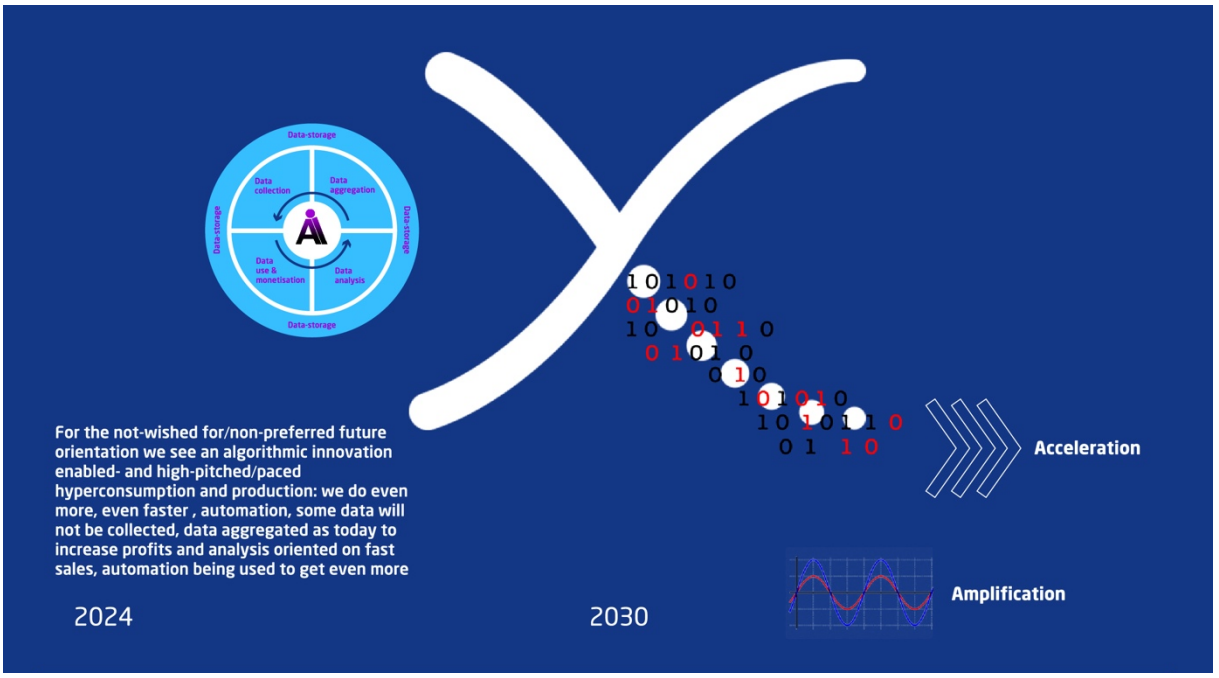

Illustration 6: AI X sustainability in 2035 – avenue 2- algorithmically intensified, hyper pitched and paced fashion industry. Own illustration together with Hanieh Zadszar

On the other hand the undeniably positive effects of AI may countered with a massive increase in production output enabled by using AI applications for marketing especially by ultra-fast-fashion players like Shein and Temu. These players use AI to speed up interactions with consumers and provide more new, to a lesser and greater extent not very sustainable products to customers whose needs for novelty and gratification are being suited by AI. These players collect in a more sophisticated manner, faster and more data on their clients needs and wishes based on AI-powered interactions on app-based styling fashion reception and fashion practice oriented ecosystems. Based on this collection of data, these players come up with new aggregations of data – e.g. in the form of more subtle personae and customer profiles as well as geographic breakdowns, which then also help to excel in data analysis. On the basis of these better analyses of data and the supply-chain-sided use of AI, with more integrated marketing insight production and supply chain management these

players are then able to monetise their data. These practices and the increase in production then leads to more, faster production and sales of more apparel. Given that these forms of data-powered and AI enabled business practices have been very successful as the success of players like Shein and Temu mirrors, in principle positive effects are counteracted. Given the existing logics in the fashion industry it is highly probable that there will be an algorithmically intensified, hyper pitched and hyper paced fashion industry.

Ethical considerations – existing biases get reinforced and amplified

Given the existing logics of a price-and brand-based fierce competition and the more myopic orientation of most fashion players which tend to "catch the low-hanging fruit" and probably refrain from massive investments in new data infrastructures new data sets and changes to business models also based on a talent shortage, it is also quite probable that the whole fashion industry will more go into avenue 2 – a more algorithmically intensified hyper-pitched industry – with even faster output of more clothing.

Given the dearth of data on sustainable qualities and that most of the players are just in train of building and integrating knowledge and wisdom on sustainable materials and on sustainable fashion and how to market more sustainable also longer product lifecycle -oriented fashion with repairs and redesigns, data enablement and AI-powering will probably result in even faster output. This means also that we will see the mirroring negative effects on sustainable development. Most important in that respect is also that cognitive biases (Lu 2020), which have already been established in the emerging knowledge economy will be further triggered to even higher relevance with progress in AI solutions, more subtle and automated, generative knowledge management and profound changes to data collection, data aggregation, data analysis and data use and monetization.

Among these cognitive biases that are at the moment already amplified are bandwagon effects (ideas, fads and beliefs grow as more people adopt them faster), groupthink, availability heuristic (relying ion immediate examples and data), Dunning-Kruger effect (the less you know, but the AI knows, the more confident you are), automation bias (relying on automated systems), digital amnesia (forgetting information that is easily retrieved via google), confirmation biases, availability cascades, status quo biases, stereotyping, authority biases, and clustering illusions. On the basis of the existing logics these biases may lead to a socially and environmentally less sustainable development oriented fashion industry so that education professionals – especially in higher education and lifelong learning and training – are called upon to safeguard more sustainable developments.

Challenges

For navigating AI transformations, higher education should be more oriented on enabling sustainable algorithmic innovation. Safeguarding that more meaningful and sustainable development relevant data are collected and then thoroughly aggregated and working together with AI developers to come up with new foundational models and use models and to safeguard the use of these models as it is also established in the EU AI Act is the order of the next ten years.

Educators should especially be oriented on providing more digital and green competency-based instruction enabling the learners to assess themselves and to spot and act on certain biases. The whole education system is challenged with providing more design considerations, more „wisdom“ not only applied knowledge with a cross-industry perspective and a perspective on sustainable development (indicator and science-based).

The education system should establish working groups and curricular elements to learn to navigate and overcome biases for negative developments and establish in students and leaders more optimism and agency based on more numeracy, digital literacy, future literacy and AI design competence. For navigating AI transformations, higher education should be especially more green competency-based (Bianchi, Pisiotis, Cabrera, Giraldez 2022). In that respect embracing sustainability values and also fostering normative transformations and bringing mother nature „back in“ with differentiated perspective on biases, more integrating indigenous and also implicit knowledge and also being oriented in more regeneratively are promising and necessary aspects. In designing micro-learning – also highly applied education, training and learning and future curricula embracing complexity for AI X Sustainability also means to establish and safeguard more system and systemic thinking. This means to cherish holism, emergence, adaptation, connectivity, critical thinking and problem framing, as fundamentally “human” prerogatives. More attention should also be given – given the biases – to work on envisioning sustainability with hands-on futures literacy, guided exploration and experimentation and fostering curiosity, which is also about to deteriorate with instant gratifications of using AI solutions. The most important aspect lies in acting for sustainability. Defining and fostering political agency and activism, collective action and individual initiative also for using AI and data more responsibly.

CONCLUSION

Given the tremendous pace of progress and investments into generative AI and its multi-faceted uptake and tweaking by fashion actors, this anticipative endeavour illustrates that there are avenues at the intersection of sustainability and AI, in which progress to the way data is collected, aggregated, analysed, used and monetised, which might trigger more sustainable development along the lines of the SDGs. This avenue of data- and AI-empowered amelioration in the next ten years, however is not

highly probable taking into account the path dependency and the existing logic of fierce price and brand-based competition in fashion. Given the already raging cognitive biases the speculation and anticipation in this paper has also shown that the second avenue to an algorithmically-pitched, hyper-accelerated fashion industry is not an avenue that should be taken in the perspective of the planet, most people and progress. It is high time for education systems to keep up with the pace and work on developing new curricula and formats fostering more digital sustainability competencies to form more desirable futures for the fashion industry.

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