The Research Direction of Emerging Human Enhancement Technology from the Perspective of Social Constructivism

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Abstract

Edinburgh School, Bath School, and Paris School are representative schools of social constructivism. The three schools put forward "strong programme," "empirical programme of relativism," and "actor-network theory," respectively. The "strong programme" emphasizes the macro research direction of the relationship between science-technology and society, the "empirical programme of relativism" attaches importance to the micro perspective of science and technology practice itself, and the "actor-network theory" pays attention to such meta issues as the ontology and epistemology of science and technology. The "outside" of technology, the "inside" of technology, and the "net" of technology constitute three directions in which emerging human enhancement technology is to be explored based on social constructivism. From the perspective of the "strong programme," macro variables such as economy, politics, culture, and society guide the direction of the evolution and development of human enhancement technology; from the perspective of the "empirical programme of relativism," micro variables such as subject, object, and intermediary of emerging human enhancement technology innovation constitute the internal driving force of its development and progress; from the perspective of the "actor-network theory," the noumenon of emerging human enhancement technology manifests itself as a "synthesis," constructed by "actors" and revealed by tracking "actors," "translation," and describing ways of interconnection. Integrating sustainability into these perspectives is crucial for ensuring that human enhancement technologies develop in a manner that promotes long-term ecological and social well-being. By aligning macro-level policies and economic incentives with sustainable development goals, fostering eco-friendly innovation practices, and creating inclusive networks that engage diverse stakeholders, these technologies can support human advancement without compromising environmental integrity or social equity. Thus, sustainability becomes a guiding principle that shapes the trajectory of human enhancement technologies, ensuring that they contribute positively to the broader goals of sustainable development.

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1 Introduction

"Enhancing oneself" has been a relentless pursuit in human society. With the development of converging technologies integrating nanotechnology, biotechnology, information technology, and cognitive science (NBIC) , emerging human enhancement technologies have come into being[1]. These emerging human enhancement technologies differ from traditional enhancement technologies by using converging technologies to regulate and enhance human physical and mental capacities, fundamentally improving human abilities. These technologies can strengthen human capacities in physical, cognitive, moral, and emotional aspects, significantly altering individuals and profoundly impacting human society as a whole. Conversely, various factors within human society can also promote or constrain the development of emerging human enhancement technologies. Social constructivism offers a perspective to explore emerging human enhancement technologies from the relationship between "technology and humanities." Representative schools such as the Edinburgh School, Bath School, and Paris School have respectively proposed the "strong programme," "relativist empirical programme," and "actor-network theory." The "strong programme" emphasizes a macro research approach to the relationship between science and society, the "relativist empirical programme" focuses on the micro perspective of technological practice itself, and the "actor-network theory" addresses the ontological and epistemological issues of technology. Based on this, the author attempts to reveal three possible research paths for emerging human enhancement technologies from the perspectives of "technology external," "technology internal," and "technology network." This exploration helps to uncover the issue of "deep technologization" brought about by emerging human enhancement technologies and broadens their research paths from the perspective of the "human-technology-world" relationship.

2 Technology External: Social Variables of Emerging Human Enhancement Technologies

The Edinburgh School emerged in the 1970s, with David Bloor and Barry Barnes as its typical representatives. They proposed the "strong programme" theory, based on the relationship between "social imagery" and knowledge, which posits that various social factors are "determinative" in the formation of knowledge[2]. The "strong" in "strong programme" signifies that all knowledge contains ineliminable or unsurpassable social dimensions. This theory insists on studying the causes of knowledge from principles of causality, impartiality, symmetry, and reflexivity. Specifically, the principle of causality asserts that any knowledge can be explained based on social reasons; the principle of symmetry suggests using the same social reasons to explain rational and irrational beliefs, correct and incorrect beliefs; the principle of impartiality emphasizes treating correct and incorrect beliefs fairly; and the principle of reflexivity posits that the sociology of scientific knowledge itself should be explained from a social perspective. David Bloor pointed out that we should focus not only on "what knowledge is" but also on "how knowledge comes to be" and "the validity of knowledge"[3]. Barry Barnes noted that in modern science and technology, the importance of "external directional influences" is unquestionable[4]. Here, David Bloor emphasizes the issues of the "source" and "validity" of knowledge, indicating that the essence of knowledge cannot be understood without considering factors external to knowledge, such as economic, political, and cultural factors, and their relationship with knowledge. Barry Barnes directly highlighted the directional role and function of external factors in science and technology. In essence, the Edinburgh School provides a macro-variable analysis method for technology, interpreting the evolution of technology from a sociological perspective. From their viewpoint, economic, political, cultural, and social factors interact with emerging human enhancement technologies, with the former having a "constructive" and "directional" influence on the latter. Based on this, we can further explore the interactive relationship

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between the two and reveal the essence and development laws of emerging human enhancement technologies.

First, economic factors such as market profit, market share, and research funding investment constrain the development of emerging human enhancement technologies. Enterprises in this field often focus on economic benefits and product market share, adhering to the principle of maximizing benefits with minimal investment to achieve their economic value. Chen Changshu discussed the "reciprocal" relationship between technology and economy[5]. He pointed out that from an economic perspective, investing in technology is necessary to convert technology into economic benefits and promote economic development. He also noted that the market is the soil for technology growth, determining the fate of technological development. Only technologies accepted, recognized, or appreciated by the market can be supported and developed, with product sales closely linked to the fate of technology. Therefore, technology must conform to market demands, be market-oriented, and aim for economic benefits. J.D. Bernal pointed out that people generally do not consciously or attempt to apply science and technology directly to benefit humanity but use them as tools for profit, evaluating science and technology based on their contributions to increasing product value and reducing product costs[6]. From the above, Chen Changshu revealed that economic investment and market demand "determine" the fate of technology, and J.D. Bernal clarified the profit-driven nature of technology and its "profitability." Both views confirm that R&D investment is the "core element" driving technological innovation[7]. The "profitability" of technology itself and its "dependence" on the economy also confirm the "directionality" and "determinacy" of economic factors on technology. Regarding emerging human enhancement technologies, their market dominance or economic benefits through expanding human capabilities or functions have been confirmed by the significant profits generated by current emerging human enhancement technologies. For example, according to data from the China Academy of Information and Communications Technology, "the global augmented reality (AR) industry market size was approximately 28 billion yuan in 2020, and it is expected to reach 240 billion yuan by 2024, with a compound annual growth rate of 66%[8]." The market for products of emerging human enhancement technologies and their economic factors guide the development direction of these technologies and even determine their development possibilities.

Second, government departments influence the development direction of emerging human enhancement technologies through research project guidelines and technology innovation system design. Government departments have always attached importance to guiding and regulating emerging technologies, such as high-tech developments similar to emerging human enhancement technologies. On the one hand, they guide the development direction of such technologies; on the other hand, they intervene and regulate emerging technologies that may negatively impact social fairness, justice, and dignity. Langdon Winner argued from two dimensions about the political implications of technology: first, technology supports the construction of political power or authority; second, some uncontrollable technologies are closely tied to specific power or authority. Therefore, he pointed out that the development and evolution of technological systems are deeply intertwined with modern politics, which is "not surprising" [9]. For example, the socialist industrialization policies of the former Soviet Union regarded technology as a "treasure" for consolidating Soviet power [10]. A scholar conducted a longitudinal study of towns and streets in Shanghai from 2012 to 2018, finding that internet technology profoundly changed the structure of grassroots power[11]. Specifically, on the one hand, the participation of technical experts in the political field can change the characteristics of political activities. Technical experts will actively participate in various public or government activities to promote and publicize such technologies, further influencing government decisions. On the other hand, technological innovation entities need to seek support from government departments in terms of research funding, educational conditions, and personnel allocation. Regarding emerging

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human enhancement technologies, political factors significantly impact them. When the development of these technologies may trigger politically sensitive issues, they will attract government attention and be regulated. For example, the gene-editing technology of babies within emerging human enhancement technologies was halted by the government due to the He Jiankui incident[12]. Conversely, if these technologies are politically beneficial, they will receive substantial support and rapidly develop.

Third, human art and cultural resources subtly support and guide the evolution of emerging human enhancement technologies. First, the design of these technologies often draws nourishment and inspiration from film culture, science fiction, and artistic design. In the field of emerging enhancement technologies, artists play a more critical role than imagined [13]. For instance, from 1978 to 1980, artist Michael Naimark proposed the concept of allowing users to browse and explore panoramic street scenes of Aspen, Colorado, interactively in "Aspen Movie Map." Forty years later, Google Street View achieved this enhanced cognitive function. Golan Levin believes that artists excel at observation and empathy, reflecting their feelings and discoveries back to the world, presenting alternative ways of understanding, feeling, and perceiving. They can ask new questions and break people's thinking stereotypes. They often prototype many "future" technologies early on. Second, the development of emerging human enhancement technologies cannot be separated from the cultural resources of the enhancement technology community and the cultural resources provided by the broader social environment. These technologies can draw support from their community's cultural resources and the broader social environment[14]. From a social and cultural atmosphere perspective, culture is the crystallization of civilization, the knowledge base and value principle for technological development, and increasingly an essential driving factor and application scenario for technological advancement [15]. We all wish to be more perfect, excel in various abilities, and find ways to become stronger, more beautiful, smarter, and more intelligent, with better memory and longer life. We study hard, exercise, take medication, and undergo plastic surgery to achieve these desires [16]. This is essentially a social culture of human pursuit of self-enhancement, significantly guiding and promoting emerging human enhancement technologies.

Fourth, social factors and emerging human enhancement technologies have a mutually promoting relationship and, under certain conditions, a mutually restrictive relationship. Regarding mutual promotion, the pursuit of social value goals generates the need for the development of these technologies, pushing them forward. In turn, the development of these technologies provides the technical assurance and conditions for pursuing a better life, changing social conditions and "triggering changes in the entire social lifestyle" [17]. Masahiko Inami depicted a societal model brought by these technologies: based on the "R-V (reality-virtuality) continuum," a seamlessly connected society of "city-town" and "individual-society" will be constructed. In this society, everyone is free from the constraints of time and space and from the limitations of mobility and cognition. Everyone can freely participate in social activities and production, exhibit their strengths, and engage in vivid and effective creative activities[18]. This societal ideal is the development goal of these technologies, guiding their evolution to a certain extent. Regarding mutual restriction, on the one hand, social factors or conditions restrict the development of enhancement technologies. These technologies aim to achieve "superhuman" value goals, which are in opposition to the concept of "ordinary people," potentially causing fear or unease among "ordinary people." When this fear or unease reaches a certain level, it becomes a social event, affecting social fairness and justice, forming social ethical issues, and thus being constrained or opposed by social forces. On the other hand, these technologies restrict the achievement of social goals. These technologies are means to achieve social goals, and their depth and breadth impact social development and the realization of value goals. For

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instance, new technologies help improve economic efficiency and promote benefits from institutional changes, "thereby inducing institutional changes"[19].

In summary, economic, political, cultural, and social factors constitute the macro-directional variables of emerging human enhancement technologies, regulating their evolution. First, as a revolutionary productive factor, these technologies promote and enhance the development of the economic base, while the economic base, in turn, promotes or constrains their development. For example, the research funding and market profits of these technologies are constraints on their development. Second, due to certain ethical risks, the government regulates these technologies to uphold political value goals or moral boundaries. Additionally, the government's policy design, research projects, and scope of these technologies can guide their macro-directional regulation. Third, human art and cultural resources, to a certain extent, become the forerunner of the development of these technologies. In their development process, artistic creation, film culture, and literary works construct various virtual "superhumans" and their transcendent abilities, often becoming the research and development direction of these technologies. Fourth, social groups or individuals promote or constrain the development of these technologies in various ways. Socially recognized emerging human enhancement technologies will receive encouragement and support from social organizations or groups; otherwise, they will be constrained or resisted.

3 Technology Internal: The Mechanisms of Emerging Enhancement Technologies

The Bath School can be seen as a dialectical synthesis of the Edinburgh School. Its representative figure, Harry Collins, adheres to two of the four "tenets" of the Edinburgh School—"impartiality" and "symmetry"—while initiating a "micro" approach to the study of scientific knowledge, proposing the "empirical programme of relativism" (EPOR)[20]. Harry Collins emphasizes fieldwork in laboratories and excels in micro-research methods. He attempts to reveal that the emergence of knowledge in lifestyles is "jointly entrenched" by multiple micro-factors [21]. This methodological approach provides a theoretical premise for exploring the emergence of new human enhancement technologies. Based on this, the author attempts to reveal the ontology of emerging human enhancement technologies through the research subject, research object, and research intermediaries.

Regarding the subject of technological innovation, it is the active factor in the R&D of emerging human enhancement technologies and an important object of study. Harry Collins believes that only knowledge derived from the "core of science" or "embedded within scientists" is genuine [22]. Compared to the traditional subjects of enhancement technology innovation, the subjects of emerging human enhancement technology innovation possess distinctive characteristics in knowledge background, value orientation, and thinking patterns. First, the knowledge background of these innovation subjects significantly influences their development. They must have a background in cutting-edge scientific theories and technical knowledge and undergo specialized academic training to possess technical operational practice abilities. The knowledge background and technical practice capabilities of innovation subjects are essential foundations for the R&D of new human enhancement technologies. Second, the value orientation of these innovation subjects will significantly impact the development of these technologies. These subjects focus on enhancing or surpassing normal human physical, cognitive, emotional, and moral capabilities. Such breakthroughs in normal human capabilities may pose certain technological risks and social ethical issues. Therefore, government departments, scientific communities, or other social organizations may take measures, including laws and regulations, to restrict or control the further development of such technologies. Third, the thinking patterns of these innovation subjects will also significantly impact their development. Unlike traditional enhancement technology subjects who adhere to a holistic "harmony between

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humans and nature" thinking pattern, these subjects adopt a reductionist approach. They aim to analyze and decompose the complex human system into specific, simple parts, attempting to enhance specific human capabilities from physical, cognitive, moral, and emotional perspectives. Under this thinking pattern, humans are no longer seen as a holistic end or purpose but as "test subjects" or "experimental fields" for exploring and enhancing partial and specific capabilities. Therefore, emerging human enhancement technologies under this thinking pattern emphasize creating supernatural and supernormal human abilities rather than harmonious coexistence between natural and technological capabilities.

Regarding the object of technological innovation, it is the target of the R&D of emerging human enhancement technologies and the material basis of their technical practices. From the perspective of technological autonomy, the objects of these technologies follow their internal logic, evolving independently without relying on human consciousness or social forces[23]. In this regard, these objects have the characteristics of self-existence, self-determination, and self-growth. Based on this, these technological innovation objects can be viewed as the technology itself, without the need to explore them from the perspective of innovation subjects. From the social constructivist perspective of the Bath School, the objects of emerging human enhancement technologies are among the factors constructing their technical knowledge. The means, paths, and products of these technologies are all factors in constructing the technology or technical knowledge. For example, propranolol, which helps reduce racial bias, oxytocin, which enhances trust, empathy, and generosity, and serotonin, which enhances justice and altruism, are all innovation objects of moral enhancement technology, constructing or "entrenching" the technology itself. Furthermore, only when biomedical and biopharmaceutical technologies develop to a certain extent will moral enhancement technologies emerge and be applied in clinical treatment and promotion.

Regarding technological innovation intermediaries, they are the means for the R&D of emerging human enhancement technologies. Harry Collins views "voltmeters, lasers, mirrors, wires, oscilloscopes, steel pipes, and concrete caves" as the real existence for detecting gravitational waves. He believes that only based on these real existences can we truly "explore" the world, not just "talk about" the world [24]. The R&D of new human enhancement technologies must rely on various intermediary tools and the procedures and methods for operating these tools. These tools, procedures, and methods can be further divided into material systems and language-symbol systems. The material intermediary system of these technologies is mainly reflected in the equipment, machinery, and energy tools used in their R&D; the language-symbol system includes both explicit language and text symbols and implicit symbols. For instance, tacit knowledge significantly influences emerging human enhancement technologies. Tacit knowledge, in contrast to explicit knowledge, is characterized by intuition and incommunicability. Both types of knowledge are acquired through practice and are interconvertible and interpenetrable[25]. In the development process of new human enhancement technologies, tacit knowledge also exists and plays an important role. The R&D of these technologies is partly a "trial and error" experimental process, requiring the support of cognitive science, computer science, psychology, physiology, and a series of scientific theories, as well as high-tech support from medical technology, genetic control technology, nanotechnology, information technology, implantation technology, and other fields. Due to the complexity of these technologies, many unclear knowledges, only tacitly understood and incommunicable, are involved in their experimental process, significantly impacting the generation of emerging human enhancement technologies.

In summary, the innovation subjects, objects, and intermediaries constitute the micro-tendency variables of emerging human enhancement technologies, forming the fundamental forces for their

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genesis. First, the value orientation, knowledge background, and thinking patterns of the innovation subjects significantly influence the design, formation, and development of these technologies. Second, the innovation objects form the targets and content of the R&D of these technologies, serving as the material foundation for their development. Only with the material foundation and prerequisites can these technologies be developed. Third, the tools, procedures, and methods for R&D as technological intermediaries constitute the guarantee conditions for developing new enhancement technologies.

4 Technology Network: The Actor-Network of Emerging Enhancement Technologies

Following the Edinburgh School and Bath School, the Paris School, represented primarily by Bruno Latour, has gained significant attention in academic circles. Latour's "Actor-Network Theory" (ANT) is a research method that presents the relationships among various "actors" based on a network model. It posits that the actors involved in practice are heterogeneous, including human and non-human factors such as nature, artifacts, and ideas. These actors interact in practice, forming a "heterogeneous network" that is interconnected and dynamically evolving[26]. In terms of current research, ANT has evolved from focusing on "science → globalization, geography, diffusion → technology → ontology, materiality"[27]. Scholars have suggested that ANT breaks the binary separation of ontology, retrieves the forgotten dimension of time, highlights non-human existence, and transcends the dichotomies of fact and value, reductionism and holism, providing a "practical analysis" paradigm for studying complex phenomena [28].

First, Exploring the Ontology of Emerging Human Enhancement Technologies Based on the Conceptual Tool of "Sociotechnical Imbroglios". From the ontological perspective of ANT, Latour argues that the objects of study in reality are neither purely natural objects nor purely social subjects, but "quasi-objects" [29]. These are hybrid entities of natural objects and social subjects, or simply, actor-networks, also referred to as "sociotechnical ensembles" or "technological artifacts"[30]. From this ontological viewpoint, emerging human enhancement technologies cannot be viewed solely as natural entities or as subjective entities; they are "actors." These "actors" can be composites of anything, such as individuals, enterprises, research institutions inventing these technologies, the material components of these technologies, and the technologies themselves. Moreover, it is suggested that the origins of these technologies cannot or should not be questioned due to their irreducibility: (1) all actors involved in the construction of these technologies participate equally, with no hierarchy of superiority; (2) the dynamic negotiation, struggle, and compromise among these actors involve no hierarchical superiority; (3) the actors possess autonomy and are not always controlled or constrained by specific subjects. Therefore, the innovative subjects, objects, and intermediaries of emerging human enhancement technologies collectively form their actors, transcending the dichotomies of nature and culture, objectivity and subjectivity, value-laden and value-neutral. Consequently, from the ontological perspective of ANT, emerging human enhancement technologies are constructed by their actors and gain their existence through the interaction with other actors.

Second, Interpreting Emerging Human Enhancement Technologies Through "Translation". Epistemologically, ANT asserts that truth exists in tracing translations within various contexts or in the continuous journey of attempts and practices, rejecting the existence of universal truth and hierarchical knowledge. Latour posits that translation is connection or universal association; temporally, knowledge before and after translation is asymmetrical[31] because no actor can be reduced to its prior state; spatially, translation implies that one "thing" becomes another "thing." Using the mechanism of translation to understand emerging human enhancement technologies means not seeking their generative starting point or exploring their essence from their intrinsic nature.

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Instead, understanding these technologies involves grasping or "knowing" them in their active practice. Vertically, these technologies continuously evolve, never retaining the same identity at any point in time, and can only be understood as translations or transformations "always en route"; horizontally, these technologies constantly develop and evolve in space, undergoing transformations within the actor-network, existing in a state of perpetual flux. ANT also elucidates the "Principle of Symmetry Generalized"[32], which posits that anthropologists must position themselves at the center to trace both non-human and human properties. Under this principle, the natural and social factors of emerging human enhancement technologies hold equal constructive significance, with each natural state corresponding to a social state. Both natural and social factors are elements that construct the technology itself, requiring explanation.

Third, Investigating the Actor Construction of Emerging Human Enhancement Technologies Using "Tracking" and "Describing" Methods. Methodologically, ANT involves following actors to describe their "associations," constructing the actor-network. This method can examine various cultural phenomena such as concepts, ideas, theories, and their interrelations. Applying this methodology to emerging human enhancement technologies reveals the construction process of the actor-network. These technologies encompass a series of actors including design invention, product prototyping, formal production, marketing, sales, technical usage, feedback, and further product improvement by producers. Additionally, this actor-network includes political institutions, media promotion, academic research, social organizations, cultural factors, and more. In this actor-network, both human and non-human actors collaborate to construct the technology, demonstrating "democratic equality." Specifically, based on ANT's methodology, the study of emerging human enhancement technologies involves: (1) developing themselves or strengthening themselves through "association," requiring an investigation into their creation, transformation, and interaction with other actors; (2) using the "inscription" research method to trace and study the technologies, such as reading materials, books, instruments, and experimental records; (3) surpassing pure technological determinism or purely social constructivist research methods, integrating both perspectives. This approach allows for an in-depth exploration of the "concrete" world of emerging human enhancement technologies, reconstructing the relationship between macro and micro factors.

In summary, from the ontological perspective of ANT, emerging human enhancement technologies manifest as "sociotechnical hybrids." These technologies are neither purely natural objects nor purely social subjects but are quasi-objects—hybrids of natural and social entities. This hybridity manifests as the actor-network of the technology. The actors of these technologies include external variables such as economic, political, cultural, and social factors, as well as internal variables like innovative subjects, objects, and intermediaries. There is no hierarchy or superiority among these variables or actors, nor can one variable be attributed to or reduced to another. These actors possess a degree of autonomy, and their "conflicts" and "negotiations" collectively construct the technology itself. Epistemologically, recognizing emerging human enhancement technologies involves understanding and interpreting their "translations," with the following implications: (1) the knowledge of these technologies is not reductionist; it changes before and after translation, with an asymmetrical relationship that cannot be explained solely based on its prior state; (2) this knowledge does not reflect the correspondence or unity between the research subject and its objective existence at any given time point; (3) this knowledge is not coherence theory-based, as it does not seek truth by integrating knowledge into a belief system or relying on coherence for truth, instead emphasizing relativity and contingency; (4) the knowledge of these technologies is always "in translation," requiring tracking and describing this transformation while understanding both human and non-human actors involved. Methodologically, studying emerging human enhancement technologies involves tracking actors and describing their interconnections, focusing on their practice, actor

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interactions, and the transformation process of the actor-network. Additionally, researching "inscriptions" related to these technologies is essential. This methodological approach transcends the dichotomy between technological determinism and social determinism, aiming to "recall" the intentionality of technological artifacts, granting them the status of actors and advocating for democratization.

The above three sections, based on the macro-variable research methods of the Edinburgh School, the micro-analysis methods of the Bath School, and the descriptive methods of the Paris School's "Actor-Network Theory," analyze emerging human enhancement technologies, revealing their connections and interactions with external and internal variables, and exploring their ontological, epistemological, and methodological issues. Naturally, the theoretical evolution from the "strong programme" to the "empirical programme of relativism" to "Actor-Network Theory" is a process filled with theoretical controversies. The "strong programme" emphasizes a relativist stance, "rejects rational models"[12], and tends towards agnosticism and subjectivism; the "empirical programme of relativism" rejects the causal relationship between beliefs about the world and objects, and struggles with the relationship between relativism and empiricism[33]; "Actor-Network Theory" disregards the capitalist mode of production and escapes the perspective of capitalist political economy critique, reflecting a post-humanist stance [23]. We should critically view these theories, adopt their strengths, and fully utilize their theoretical advantages to explore the interactive relationship between emerging human enhancement technologies and society, deeply revealing their intrinsic laws and the interaction mechanisms with other constructive factors, enabling them to better serve human self-improvement and comprehensive development.

5 Conclusions

The exploration of emerging human enhancement technologies (HET) through the lens of social constructivism, when integrated with sustainability considerations, offers a comprehensive understanding of the multifaceted interactions between technology, society, and the environment. Social constructivism, as represented by the Edinburgh School, the Bath School, and the Paris School's Actor-Network Theory (ANT), provides three distinct yet interrelated perspectives—macro, micro, and networked—that are essential for understanding the evolution and impact of HET. From the macro perspective, as emphasized by the Edinburgh School's "strong programme," economic, political, cultural, and social factors play a pivotal role in guiding the development of HET. The market profitability, government regulations, and cultural acceptance are critical external factors that shape the trajectory of these technologies. When viewed through the lens of sustainability, it becomes evident that responsible governance and policy-making are crucial. Policies must be designed to ensure that HET development aligns with sustainable development goals, promoting economic growth that does not compromise environmental integrity or social equity. This includes creating regulatory frameworks that balance innovation with ethical considerations, ensuring that the benefits of HET are equitably distributed and do not exacerbate existing inequalities.

The micro perspective, rooted in the Bath School's "empirical programme of relativism," highlights the internal dynamics of HET development. This includes the knowledge background, value orientations, and cognitive approaches of the innovators, as well as the technological objects and mediating tools they utilize. For sustainability, the internal development processes of HET must prioritize eco-friendly practices, such as minimizing resource consumption and reducing environmental footprints. Innovators should adopt sustainable design principles that consider the entire lifecycle of the technology, from development to disposal, ensuring that HET contribute positively to both human capabilities and environmental health.

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ANT's network perspective offers a nuanced understanding of how heterogeneous actors, including human and non-human entities, interact within the network of HET. This perspective underscores the importance of creating inclusive and democratic networks that incorporate diverse stakeholders, such as marginalized communities, environmental advocates, and policymakers. These inclusive networks ensure that the development of HET is guided by a broad range of interests and values, promoting transparency and accountability. By engaging multiple stakeholders, the development process can address potential risks and ethical concerns, fostering public trust and ensuring that the technologies are developed in a socially responsible manner.

Integrating sustainability into the development of HET requires a multi-dimensional approach that encompasses regulatory frameworks, eco-friendly innovations, ethical practices, and stakeholder engagement. Regulatory frameworks should be established to protect individual rights, promote equitable access, and ensure the responsible use of HET. Eco-friendly innovations should prioritize sustainability, utilizing renewable resources and minimizing waste. Ethical practices must address concerns related to privacy, autonomy, and consent, ensuring that the development of HET is guided by principles of fairness and justice. Engaging diverse stakeholders through dialogue and collaboration is essential for ensuring that the development of HET is inclusive and considers a wide range of perspectives.

In conclusion, the integration of social constructivism and sustainability provides a holistic approach to understanding and guiding the development of emerging human enhancement technologies. By considering the complex interactions between technology, society, and the environment, and by prioritizing sustainability, we can ensure that HET contribute to human advancement in a manner that supports long-term ecological and social well-being. This approach not only enhances the societal impact of these technologies but also ensures that they align with the broader goals of sustainable development, fostering a future where technological innovation and sustainability go hand in hand.

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Conflict of Interest

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