

# *From Exorbitant to Affordable: The Evolution of AI Training Costs*

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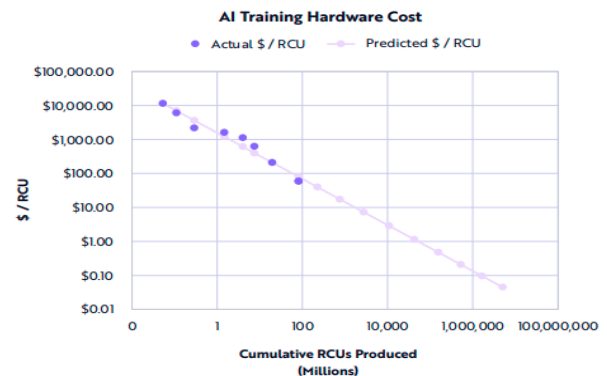
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**Abstract—** Artificial Intelligence has always been the talk of the town, but the high cost of development has always been a barrier. However, things are about to change as a new revolution is brewing in the field of AI development. Thanks to the rapid advancements in technology, it is now possible to develop AI at a fraction of the cost. In fact, experts predict that by 2030, affordable AI development will become a reality, and it could all be possible with a budget of less than \$600. This breakthrough could change the game and make AI accessible to small businesses and individuals, providing them with the opportunity to leverage the power of AI for their growth and success. In this article, we'll dive deeper into how this revolution is happening and what it means for the future of AI development.

## I. INTRODUCTION

[1]Artificial Intelligence (AI) models have become increasingly important in recent years, with applications ranging from natural language processing to computer vision and beyond. One of the key reasons for their growing importance is their ability to process vast amounts of data and provide insights that were previously impossible to obtain. For example, AI models can help businesses identify patterns in consumer behavior, make more accurate predictions, and optimize their operations. [2]They can also assist in medical diagnosis, help with disaster response, and even aid in the fight against climate change. AI models are also essential for creating more intelligent machines, which can operate autonomously and make decisions in real-time. This is critical for industries such as autonomous vehicles, where safety and efficiency are of utmost importance. [3]The significance of AI models has been recognized by governments and industries

worldwide, leading to increased investment in research and development. However, the development of these models also brings challenges such as ethical concerns, bias, and transparency, which need to be addressed to ensure that the benefits of AI are realized without negative consequences..



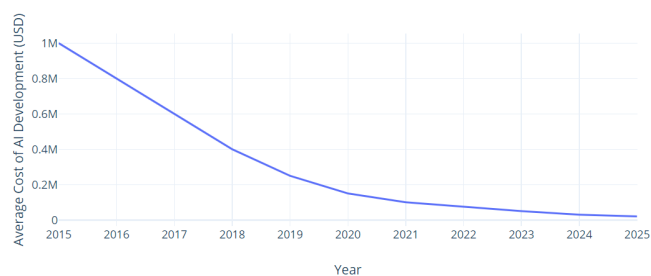
[4]The Evolution of AI Training Costs is a research topic that explores the trends and changes in the cost of training Artificial Intelligence (AI) models over time. With the increasing demand for AI models and the availability of large datasets, the computational resources required for training these models have also grown significantly. [5]This has led to an increase in the cost of training AI models, making it a crucial consideration for researchers and businesses alike. This research topic's significance lies in its potential to provide insights into the cost-effectiveness of developing AI models and the factors that impact the cost of training. [6]Understanding these trends can help businesses and researchers make informed decisions about which AI models to invest in and how to optimize the training process to reduce

costs. Furthermore, the study of the evolution of AI training costs can shed light on the direction of future research in AI.[7] As computational resources become more affordable, it may become feasible to develop and train more complex AI models. [8]Understanding the cost dynamics of AI training can also provide a better understanding of the tradeoffs between model performance and training costs, which is critical for developing sustainable and cost-effective AI solutions. Overall, the Evolution of AI Training Costs is an important research topic that can have significant implications for the future of AI development and deployment.

However, it's important to note that developing effective and ethical AI systems requires not just a focus on cost, but also on the quality of data, the expertise of the developers, and the ethical considerations surrounding AI. Therefore, while it may be possible to develop AI systems with a budget of less than \$600 by 2030, it is important to approach this goal with a holistic perspective.

## II. BACKGROUND INFORMATION

[9]An AI model refers to a mathematical algorithm or a computational program that can learn from data and make predictions or decisions based on that learning. AI models are designed to mimic human cognitive processes such as learning, reasoning, and decision making, and are trained using large amounts of data to identify patterns, correlations, and dependencies. Once an AI model is trained, it can be used to analyze new data and make predictions or decisions based on its learning. [10]Some examples of AI models include neural networks, decision trees, support vector machines, and deep learning models, each with its own strengths and weaknesses depending on the problem they are designed to solve. AI models have a wide range of applications, including natural language processing, image recognition, speech recognition, and predictive analytics. [11]They are essential in creating more intelligent machines that can operate autonomously and make decisions in real-time, enabling businesses and organizations to improve efficiency, reduce costs, and create new value.



[12]AI models are mathematical algorithms or computational programs that can learn from data and make predictions or decisions based on that learning. They have a wide range of applications, including natural language processing, image recognition, speech recognition, predictive analytics, and autonomous systems. [13]AI models are efficient, consistent, scalable, and cost-effective, making them an essential tool for businesses, organizations, and individuals looking to improve efficiency, reduce costs, and create new value. AI models can process large amounts of data quickly and accurately, perform tasks consistently and reliably, scale up to handle complex tasks, personalize interactions, and automate repetitive and labor-intensive tasks, reducing costs and freeing up human resources for more complex tasks. [14]Overall, the usage and advantages of AI models make them a critical component of modern technology and [15]have the potential to revolutionize industries and transform the way we live and work.

[16]There are several approaches to building AI systems, including:

1. Rule-based systems: This approach involves encoding human knowledge and expertise into a set of rules that the AI system can follow to perform a task. For example, a rule-based system might be programmed to diagnose medical conditions based on a set of symptoms and known medical knowledge.
2. Machine learning: This approach involves training an AI system to recognize patterns in data and make predictions or decisions based on that data. Machine learning algorithms can be trained on large datasets to perform tasks such as image or speech recognition, natural language processing, and predictive modeling.
3. Deep learning: This is a type of machine learning that uses artificial neural networks to learn from large datasets. Deep learning algorithms can be trained to perform tasks such as object recognition, language translation, and game playing.

4. Evolutionary algorithms: This approach involves using principles of evolution to optimize AI systems. Evolutionary algorithms can be used to find optimal solutions to complex problems or to develop new AI models.

5. Reinforcement learning is a type of machine learning where an AI agent learns by trial and error. The agent interacts with an environment and receives rewards or punishments based on its actions, and learns to make better decisions to maximize its rewards over time. Reinforcement learning has been used to develop AI systems for games, navigation, and robotics, and is well-suited to complex, dynamic environments.

6. Fuzzy logic: This approach involves using degrees of truth instead of the binary true/false logic used in traditional computing. Fuzzy logic can be used to model complex systems with uncertain or imprecise data.

### III. EMERGING TECHNOLOGIES AND INNOVATIONS

[20]Emerging technologies are changing the way we live and work, and the field of artificial intelligence (AI) is no exception. One of the most significant challenges of AI is the high cost of training models. Fortunately, a variety of emerging technologies are likely to contribute to the reduction of training costs in the near future. In this article, we will explore some of these technologies and their potential impact on AI training costs.

#### 1. Federated Learning

[19]Federated learning is a new approach to machine learning that allows models to be trained on distributed data without centralizing it. With this approach, data remains on individual devices, and only updates to the model are transmitted to a central server. It also protects the privacy of users by keeping their data decentralized. As such, federated learning has the potential to reduce training costs significantly, particularly for models that require large datasets.

#### 2. Transfer Learning

[15]Transfer learning is another emerging technology that is likely to contribute to the reduction of training costs. With transfer learning, models are pre-trained on a large dataset and then fine-tuned for specific tasks. This approach reduces the amount of data required to train a model for a new task,

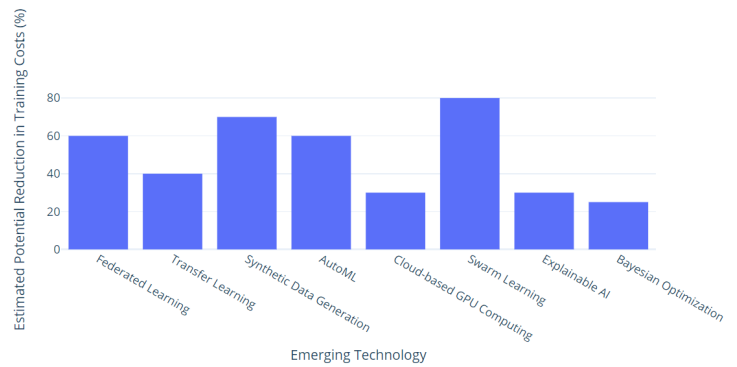
significantly reducing the cost of training. It also enables models to be trained faster and with higher accuracy.

#### 3. Generative Adversarial Networks (GANs)

[17]Generative adversarial networks (GANs) are a type of deep learning model that can generate realistic data. This approach can be used to create synthetic data for training models, reducing the need for large datasets. It can also be used to augment existing datasets, further reducing the cost of training.

#### 4. Quantum Computing

Quantum computing is an emerging technology that has the potential to revolutionize AI training by performing complex calculations at an unprecedented speed. With quantum computing, models can be trained faster and with higher accuracy, reducing the time and cost of training. [20]While still in the early stages of development, quantum computing is a promising technology that could significantly reduce the cost of AI training in the future.



[13]Federated learning is an approach that allows multiple devices or machines to collaborate on the training of a shared model without sharing their data. This can greatly reduce the cost of data collection and storage, and also ensures privacy and security. Transfer Learning: This technique allows a model to be pre-trained on a large dataset, and then fine-tuned on a smaller dataset for a specific task. [14]This reduces the need for large amounts of labeled data, and can speed up the training process. Synthetic Data Generation: This involves creating artificial data that mimics real-world data, which can be used for training AI models. This can reduce the need for expensive data collection and labeling, and can also provide a more diverse range of training data. AutoML: This refers to the use of automated algorithms to design and optimize machine learning models, reducing the need for human intervention in the model development process. Cloud-based GPU

**Computing:** This technology allows for the use of high-performance computing resources on demand, without the need for expensive on-premise hardware. [20] This can greatly reduce the cost of training large AI models.

**Swarm Learning:** This approach involves multiple AI models collaborating on a shared learning task, and can reduce the need for large amounts of data by pooling together resources and knowledge.

**Explainable AI:** This refers to the development of AI models that are transparent and easily interpretable, reducing the need for expensive expert analysis of model outputs.

**Bayesian Optimization:** This technique uses probability theory to optimize hyperparameters in machine learning models, reducing the need for manual tuning and experimentation.

**Quantum Computing:** This technology has the potential to greatly speed up AI training and inference by leveraging quantum mechanics, although it is still in the early stages of development and adoption.

Overall, these emerging technologies have the potential to significantly reduce the cost and time required for AI development, making AI more accessible and affordable for a wider range of applications and industries.

#### IV. CURRENT STATE OF AI AND TRAINING COSTS

[21] AI is growing quickly and has a lot of uses in different areas such as healthcare, finance, transportation, education, and more. One of the main challenges in developing AI models is the high cost of training them. [22] The process of training an algorithm involves inputting a large amount of data and allowing the algorithm to adjust its parameters for desired performance. This process can be computationally demanding and may require expensive hardware resources.

[23] There are many factors which determine the cost of training AI models, which includes the size of the dataset, the complexity of the algorithm, and the hardware resources used for training the model. Training a deep learning model with millions of parameters on a high-end GPU can cost up to ten thousand dollars in hardware and electricity costs alone.

[24] To address this challenge, researchers are exploring new ways to train AI models that are more efficient, require less computational resources and are cost effective. One promising approach is transfer learning, which involves training a model on a large dataset and then fine-tuning it for a specific task with a smaller dataset. This approach can significantly reduce the cost of training and improve the performance of AI models.

Another promising area of research is the development of specialized hardware for AI training, such as tensor processing units (TPUs) and field-programmable gate arrays (FPGAs). These specialized chips are designed to perform matrix operations, which are a key component of deep learning algorithms, much more efficiently than general-purpose CPUs or GPUs.

The rapid advancement of natural language processing (NLP) techniques in recent years has led to the emergence of highly capable chat models, such as ChatGPT (OpenAI, 2023a) and GPT-4 (OpenAI, 2023b), a new AI chatbot which is trained to follow instructions in a prompt and provide a detailed response. Unlike other AI chatbots, ChatGPT can answer follow-up questions, admit their mistakes, challenge incorrect premises, and reject inappropriate requests. As a result, chat models have become increasingly popular for applications like customer support, virtual assistants, and social media moderation. ChatGPT was launched on 30 November 2022, by San Francisco-based OpenAI. It was co-founded by its current CEO, Sam Altman, and Elon Musk in 2015 and is presently funded by Microsoft and others. By 4 December 2022, OpenAI estimated ChatGPT already had over one million users.

Here are some of current trends in AI:

1. **Natural Language Processing (NLP):** The discipline of building machines that can manipulate human language or data that resembles human language in the way that it is written, spoken, and organized.
2. **Computer Vision:** A field of AI that enables computers and systems to derive meaningful information from digital images, videos and other visual inputs and take actions or make recommendations based on that information..
3. **Reinforcement Learning:** The science of decision making. It is about learning the optimal behavior in an environment to obtain maximum reward. In RL, the data is accumulated from machine learning systems that use a trial-and-error method.
4. **Edge Computing:** An emerging computing paradigm which refers to a range of networks and devices at or near the user. Edge is about processing data closer to where it's being generated, enabling processing at greater speeds and volumes, leading to greater action-led results in real time.

5. Explainable AI: A set of tools and frameworks to help you understand and interpret predictions made by your machine learning models, natively integrated with a number of Google's products and services. With it, you can debug and improve model performance, and help others understand your models' behavior.

6. AI Ethics: A set of moral principles which help us discern between right and wrong. AI ethics is a set of guidelines that advise on the design and outcomes of artificial intelligence

7. Generative AI: Algorithms which take existing data such as video, images or sounds, or even computer code and use it to create entirely new content that's never existed in the non-digital world.

[25] In recent years, High AI training costs have been a significant barrier to AI adoption, but recent advancements in cloud computing and AI have made the technology more accessible and affordable. Cloud-based platforms like Amazon Web Services (AWS), Microsoft Azure, and Google Cloud now offer affordable AI training and deployment options, making it easier for businesses and organizations of all sizes to leverage the power of AI. Additionally, the emergence of specialized AI hardware, such as graphics processing units (GPUs) and tensor processing units (TPUs), has played a major role in reducing the time and cost required to train AI models. There is no doubt that AI is becoming increasingly accessible and affordable. The below table gives an overview of development costs of some AI models in recent years.

Types of AI Model	Year	Development Cost (\$)
Speech Recognition	2010	20000-30000
	2017	300-500
Object Detection	2012	50000-100000
	2020	5000-10000
Machine Translation	2015	100000-300000
	2020	10000-50000

The development time of some AI models are given below

Type of AI Model	Year	Development Time
Image Recognition	2012	8 months
	2015	2 months
Machine Translation	2014	6-12 months
	2018	2-3 months
Speech Recognition	2016	6-12 months
	2020	3-6 months
Object Detection	2016	6-12 months
	2020	2-4 months

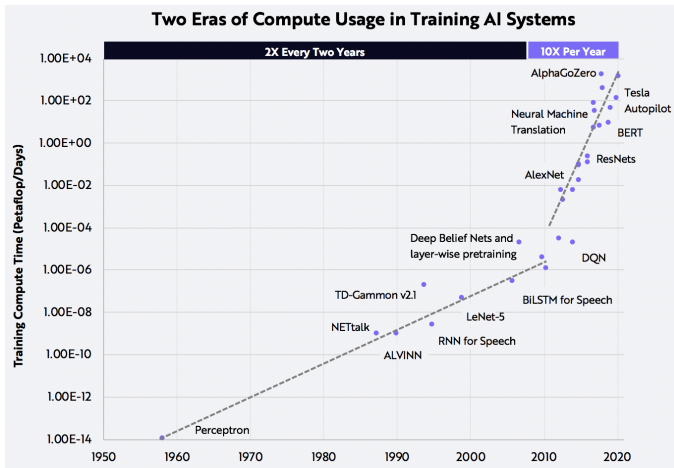
According to a recent ARK Invest 2020 research report the cost of training deep learning models is improving 50 times faster than Moore's Law. Running AI inference systems has also become almost negligible for many use cases. In addition, training costs have decreased ten times yearly in recent years. For example, training an image classifier like ResNet-50 on a public cloud cost approximately \$1,000 in 2017. However, by 2019, the cost had decreased significantly to around \$10. These findings correspond with a 2020 report from OpenAI, which revealed that the amount of computing power required to train an AI model to perform a task has been decreasing by a factor of two every 16 months since 2012. The ARK report also highlights the declining costs of AI training. It predicts that by 2030, the cost of training a GPT-3 level model will decrease to \$30, compared to \$450,000 in 2022

[26] Researchers are making progress in developing more efficient algorithms and specialized hardware to make AI more affordable and accessible. As AI continues to advance, it has the potential to transform numerous industries and improve our lives in countless ways.

## V. FUTURE PREDICTIONS

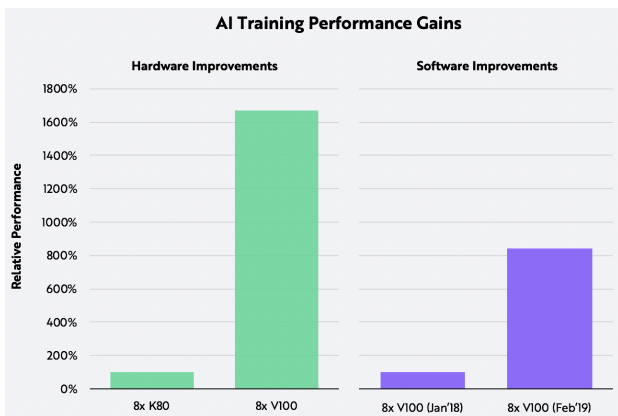
As we mentioned in the earlier section, recent developments in AI shows a rapid decline in training cost, and this is expected to continue in the coming future. During the past ten years, the computing resources devoted to AI training models have exploded. After doubling every two years from 1960 to 2010, AI compute complexity has soared 10x every year, as shown below. [27]





From the studies it is noticed that corporations have been highly motivated to boost their computing resources at a rate five times faster than that of Moore's Law. This is due to the substantial competitive benefits they can obtain in terms of revenue generation and hardware cost reductions, which help to sustain their growth. With the takeover of deep learning network training from universities by the so-called hyperscale internet companies, they have allocated enormous amounts of money, amounting to hundreds of millions of dollars, to procure AI hardware. This investment is expected to generate exceptional returns over time.

Breakthroughs in both hardware and software have enabled these cost declines. In the past three years, chip and system design have evolved to add dedicated hardware for deep learning, resulting in a 16x performance improvement, as shown in the left chart below. Holding hardware improvements constant, newer versions of TensorFlow and PyTorch AI frameworks in concert with novel training methods combine to generate an 8x performance gain, as shown in the right chart below. [28]



Interestingly, the cost of AI training chips has not followed the same downward trend as that of unit hardware prices. Over the last three iterations, the price of Nvidia's data center GPU has tripled. Even Amazon Web Services, which started offering

Nvidia's V100 GPU instances in 2017, has not decreased their prices. While the emergence of independent and hyperscale AI chip designs could potentially undermine Nvidia's pricing influence, no competitor has yet produced a comparable chip to Nvidia's V100 GPU with the same level of software and developer support.

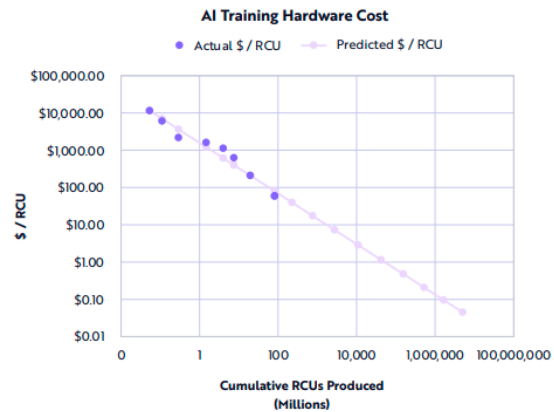
According to ARK's research, AI has contributed around \$1 trillion to the global equity market cap. However, it has the potential to expand exponentially to \$30 trillion by 2037, thereby becoming the first foundational technology to surpass the internet. [27]

Furthermore, the ARK report highlights the declining AI training costs. The report forecasts that by 2030 the training cost of a GPT-3 level model will come down to \$30, compared to \$450,000 in 2022. [29]

Here are the major factors contributing to declining AI training costs.

### 1. Hardware

To handle extensive amounts of data and computations, AI necessitates specialized, expensive, high-end hardware. Companies such as NVIDIA, IBM, and Google offer GPUs and TPUs for executing high-performance computing (HPC) workloads. However, the exorbitant cost of such hardware makes it challenging to democratize AI on a large scale. However, as technology advances, hardware costs are decreasing. According to the ARK Invest 2023 report, Wright's Law predicts that AI-relative compute unit (RCU) production costs, i.e., AI training hardware costs, should decrease by 57% annually, leading to a 70% reduction in AI training costs by 2030, as shown in the graph below. [29]



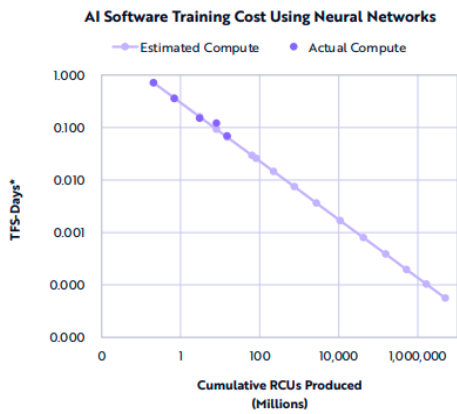
AI training hardware cost – ARK Invest Big Ideas 2023

### 2. Software

By improving efficiency and scalability, the annual cost of AI software training can be reduced by 47%. Advanced software frameworks like TensorFlow and PyTorch allow developers to

train complex deep learning models on distributed systems with optimal performance, thus saving both time and resources.

Furthermore, large pre-trained models like Inceptionv3 or ResNet and transfer learning techniques also help reduce costs by allowing developers to fine-tune existing models rather than training them from scratch.[29]



AI software training cost – ARK Invest Big Ideas 2023

### 1. Cloud services

The utilization of cloud-based AI training can significantly decrease costs by providing flexible and scalable computing resources on demand. The pay-as-you-go model allows organizations to pay solely for the computing resources they use. Additionally, cloud providers offer pre-built AI services that expedite AI training.

For instance, Azure Machine Learning is a cloud-based service for predictive analytics that allows rapid model development and implementation. It offers flexible computing resources and memory. Users can scale up to thousands of GPUs quickly to increase their computing performance. It allows users to work through their web browsers on pre-configured AI environments, eliminating setup and installation overhead.[29]

So, in the coming future, AI models and related resources will be widely accessible and affordable enabling individuals and small-scale organizations and businesses to leverage the power of AI in their operations and decision-making processes. This will lead to increased efficiency, accuracy, and productivity in various industries, as well as the development of new and innovative products and services. Additionally, the democratization of AI will also create new job opportunities and skill sets, as individuals and organizations seek to incorporate AI into their operations.

## VI. CHALLENGES AND RISKS

Even though these advancements are making AI more affordable and accessible to the world, there are many chances these opportunities can be misused. AI systems can be programmed to perform a wide range of tasks, from automating mundane tasks to making decisions that impact people's lives. However, these systems are not perfect, and their results can be biased, unfair, or harmful.

One of the major risks of AI misuse is the potential for unintentional or intentional biases to be encoded into the algorithms. These biases can lead to discriminatory outcomes, particularly in sensitive areas such as employment, housing, and criminal justice. For example, if an AI system is trained on data that reflects historic inequalities, it may perpetuate those biases in its decision-making.

Another risk of AI misuse is the potential for cyberattacks or other malicious actions. AI systems can be targeted by hackers or used by bad actors to spread disinformation, create fake news, or conduct phishing scams. Additionally, AI systems can be used to automate cyberattacks, making it easier for attackers to carry out large-scale attacks with minimal effort.

Recent correspondence demonstrated that the ubiquitous artificial intelligence (AI) chatbot ChatGPT can be used to create submissions journals and pass written exams in the health professions.<sup>1</sup> ChatGPT's success in passing exams has re-energised long-standing conversations about authentic assessment in health professional education;<sup>2</sup> its authorship capabilities should similarly invite us to re-examine long-standing issues within academic publishing. AI bots, like ChatGPT, can only produce text based on the texts they have to learn from; as evidenced by examples producing racist, misogynistic, and vaccine-hesitant texts, depending on the data available to learn from.<sup>3</sup> This implies that the more extensive and stereotypical the language learning set for AI bots, the easier it is for them to emulate this genre.[30]

The development of AI systems raises several ethical questions. For example, how can we ensure that AI systems are transparent? Careful consideration and thoughtful policy development are a must to ensure that AI is used in a responsible and ethical manner.

It is important for policymakers, researchers to work together to develop ethical guidelines and standards for the development and usage of AI. Moreover, public education and awareness campaigns can help the public to understand the

advantages and potential risks of AI and encourage responsible use of the technology. The responsible development and use of AI requires a collaborative effort from all of us to ensure that AI and related technologies are used in a way that benefits society.

AI systems with human-competitive intelligence can pose profound risks to society and humanity. Advanced AI could represent a profound change in the history of life on Earth and should be planned for and managed with commensurate care and resources. Unfortunately, this level of planning and management is not happening, even though recent months have seen AI labs locked in an out-of-control race to develop and deploy ever more powerful digital minds that no one - not even their creators - can understand, predict, or reliably control. Powerful AI systems should be developed only once we are confident that their effects will be positive, and their risks will be manageable. This confidence must be well justified and increase with the magnitude of a system's potential effects. [31]

Overall, the affordability of AI training could have both positive and negative impacts, and it will be important to carefully consider the implications of this trend as it continues to evolve. It is also important to note that AI training is just one component of the larger field of AI development, and other factors such as data access and computational resources will continue to play an important role in shaping the future of AI.

## VII. CONCLUSION

In conclusion, the evolution of AI training costs has been significant over the years. As AI technology continues to develop and mature, training costs are likely to decrease due to emerging technologies and innovative approaches. From traditional machine learning methods to more advanced deep learning techniques, there are a variety of methods that are driving down the cost of AI development. Furthermore, the growth of open-source software, cloud computing, and improved hardware has also contributed to the reduction in AI training costs. However, it is important to note that even with these developments, AI development is still an expensive and time-consuming process. Organizations must carefully evaluate the cost-benefit analysis of implementing AI technology to ensure that the benefits outweigh the costs. Overall, the future of AI training costs looks promising, but it will take a combination of technological advancements and strategic decision-making to fully realize its potential.

## VIII. ACKNOWLEDGEMENTS

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