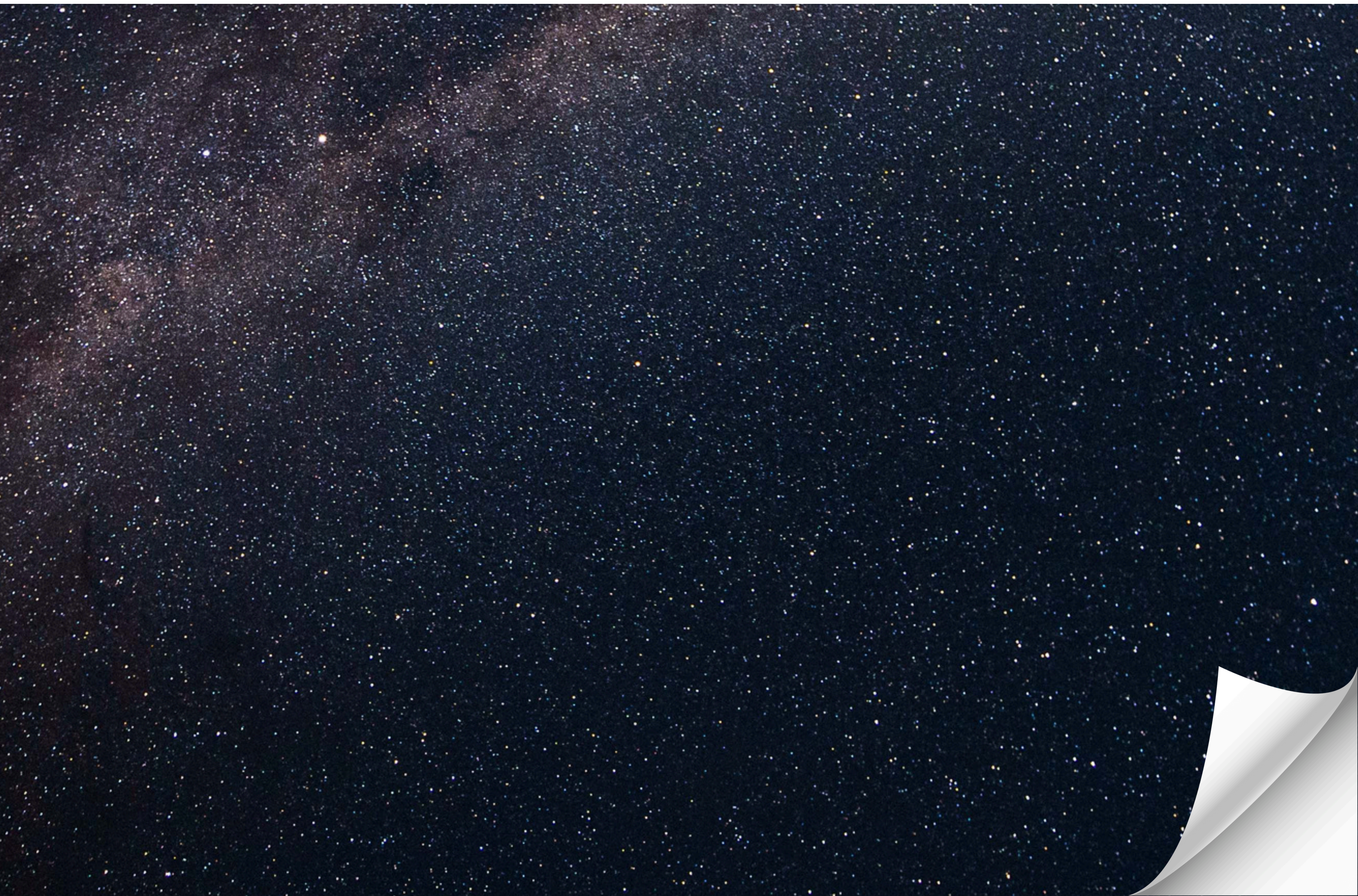
BENDING THE LEARNING SPACE WITH ARTIFICIAL INTELLIGENCE



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For over 15 years, I have been dedicated to advancing learning sciences and technology. My expertise lies in understanding and transforming human behavior, now increasingly through the lens of artificial intelligence.

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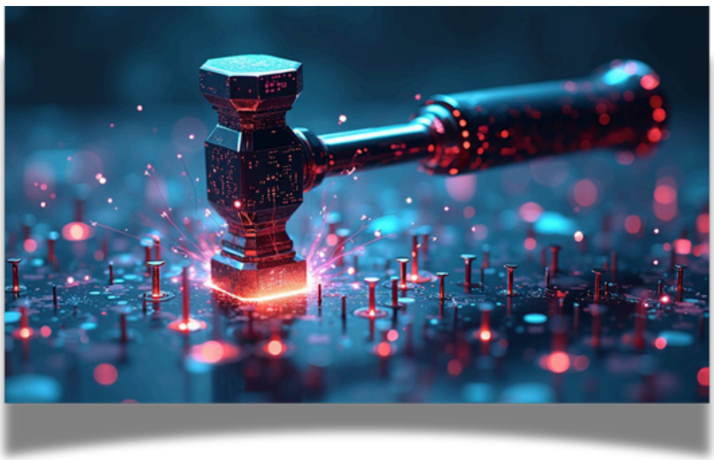
Original Source

The relationship between technology and learning has always been complex and often misunderstood. We've seen both exaggerated expectations and overlooked opportunities, two sides of the same coin, when applying technology to enhance learning experiences. This comprehensive essay is my personal perspective on how we can truly harness artificial intelligence as a transformative tool for education.

Instead of treating AI as a hammer and every problem as a nail, let's revisit our existing knowledge in the context of AI's true strengths and limitations. By understanding its new capabilities and boundaries, we can create meaningful, impactful learning experiences.



INTRODUCTION

Conversations surrounding Artificial Intelligence (AI) technologies often center on specific applications and tools. This trend is especially prevalent in the education and learning technologies in particular. While practical implementations are undeniably important —and I fully acknowledge their significance— there is an urgent need to step back and assess the broader, deeper impact that the new generation of AI technologies can have on learning experiences. I believe we must begin by conceptualizing these technologies' capabilities in relation to the nature of learning itself, allowing us to envision scenarios that go beyond the obvious use cases and applications.

In response to this need for a wider perspective, I am introducing a framework that explains the effects of AI on individual learning experiences. I call this framework "Bending the Learning Space with Artificial Intelligence" It offers a conceptual model designed to help us understand how AI has the potential to reshape the foundational aspects of learning activities.

This model introduces the idea of a "learning space," which encompasses all forms of acquirable knowledge and skills. Within this "universal learning space," we can define specific learning spaces for particular domains. An individual's interaction with this space constitutes their ""learning experiences."

I propose that AI technologies are already expanding the range of possible actions within this space, enabling new learning experiences through novel interactions.

The impact of AI on this "learning space" can be analyzed through four key components:

Space | Time | Form | Resource

THE LEARNING SPACE

The concept of a learning space enables us to think about the learning process in a more abstract yet flexible way. It helps us understand learning phenomena by using metaphors from physical and geometric spaces, which are well-suited for formulating analytical relationships and drawing meaningful inferences.

In this section, I will explain how the learning space corresponds to actual learning experiences.

In the context of the learning space, the act of learning is analogous to "movement"—moving from point A to point B. Point A represents your current level of knowledge and skills, while point B represents your desired or targeted level. The greater the gap between your current and targeted levels, the farther apart these points are situated within the learning space.

Like any movement between two points, this process takes time. Furthermore, one would need a vehicle and a route to facilitate the movement.

In this analogy:

The route —or the spatial dimension of the movement— is equivalent to the curriculum or instructional design that guides the learner along an efficient path toward their learning goals.

The vehicle symbolizes the learning materials, as they are the tools that make progression toward the learning objectives possible.

The time spent moving through the learning space represents the actual time required to achieve the targeted level of proficiency.

The route, the time and the vehicle. These are the essential elements required for **movement in the learning space.** However, a more fundamental requirement exists:

> ***Movement requires energy***

The further the destination, the more energy is required to reach it.

As the fourth and final element of this analogy, **energy corresponds to the total amount of resources** — such as workforce, expertise, technology, or financial investment—allocated to support an individual's learning journey.

AN EXAMPLE TO ILLUSTRATE THE ANALOGY

Let's apply our analogy to a real-life scenario to better understand how it can be used to facilitate learning. Consider the task of teaching a software engineering expert how to use a new version of a commonly used library. This would require modest resources —perhaps just a few hours, access to documentation, and some practice sessions.

In terms of the learning space, **this expert needs minimal energy to traverse a short distance.** In contrast, teaching a sophomore computer sciences student with no prior experience how to train a neural network from scratch would demand extensive resources. This could take months, or even a full year, to ensure that all the necessary foundational knowledge is acquired. This process would involve:

- A well-designed curriculum covering topics from the basics to more advanced applications,
- Expertise from qualified instructors,
- Access to essential software and hardware,
- Regular assessments and feedback,
- High-quality examples and comprehensive learning materials, among other resources.

In this scenario, **the student would need to invest significant energy to reach the distant goal, progressing through various milestones along the way**, as it would be impractical to make the journey in one step. This is where Artificial Intelligence enters the picture. The concept of **"bending the space"** relates directly to the idea of mass. As Albert Einstein demonstrated, mass and energy are deeply intertwined. **By reducing the energy —or resources— needed for learning, AI has the potential to bend the learning space, making previously distant learning goals more accessible or previously impractical instructional design approaches feasible.**

EXPANDING ON THE “ENERGY”

If we can harness sufficient energy, we could theoretically travel at speeds close to the speed of light, where spacetime bends dramatically. In such cases, the time required, the route, and the use of the vehicle would all undergo extreme alterations.

In learning sciences, **“energy” has always been a limiting factor for many key concepts, such as personalization, adaptiveness, addressing individual differences, and creating constructive learning environments.** We know “what works” and “what should be done” to create better learning experiences. However, turning these principles into scalable solutions has always been easier said than done because of the massive resources needed to implement them at scale. In short, we lacked the enormous amount of energy required.

If bending the learning space comes down to “energy,” this may be the perfect time to revisit what we already know. The new generation of artificial intelligence models is **“pre-trained” and “generative”** in nature. Years of accumulated efforts and historically large investments in AI technologies have concentrated an unprecedented amount of energy within these systems. **If we ever had a significant enough “mass” to bend the learning space, this is likely it.**

Let me explain why.

Transformer-based model architectures have enabled AI systems to develop a contextual understanding of vast amounts of information across various data formats. Something that has never been possible before. These AI systems can now ingest multimodal data and interpret it in light of their “pre-trained” knowledge of the world. Moreover, these models can “generate” structured and comprehensive outputs, enabling a two-way interaction with a broad and diverse range of inputs. **I argue that a well-orchestrated system of these AI systems already possesses the energy we need to implement and scale learning solutions across multiple domains.**

Thanks to the two-way communication powered by immense pre-trained knowledge, and the ability to process "new knowledge" with this foundation, **we can now achieve more with fewer resources.**

Of course, as in any closed system, **"the total amount of energy must remain constant"** — in this case, the closed system being a given learning space. So if we finally have concentrated enough energy to bend the space, it must have been harnessed through spending large amounts of energy in the first place. **Fortunately, the tech industry has paid this energy price for us in advance.**

With the leverage provided by generative and pre-trained transformers (the full form of the well-known GPT), we can dramatically alter:

- **How we define and follow routes within the learning space.** Instructional design can now become genuinely flexible and adaptive, personalizing the learner's journey toward their goals.

- **The time required to reach a particular point in the learning space.** With our newfound ability to "bend" the learning space, learners can now "teleport" through it, allowing us more freedom in determining the timing of learning activities.

- **The form of learning content and how easily we can change that form on demand.** With the highly capable and efficient machinery of new-generation AI systems, we can now modify the learning "vehicle" and its configuration based on the learner's needs, rather than being constrained by logistical factors.

In conclusion, I recommend approaching AI applications for instructional purposes from a perspective that revisits fundamental learning principles in light of these new technical possibilities.

3 DIMENSIONS OF THE LEARNING SPACE

So far, we have introduced the concept of the learning space and how the energy — i.e., the resources required to facilitate learning activities — can bend this learning spacetime. In the following section, I will elaborate on what “bending” means for the three dimensions of the learning space.

1. SPACE

In the context of learning, **the "space" refers to how learners progress through the content**, whether it's a curriculum or a single video lesson. It is the spatial dimension of the movement for that matter.

Traditionally, learners consume content in a linear order, predefined by instructional designers. Disrupting this order can lead to learning gaps or misunderstandings. Instructional designers and subject matter experts act as "***cartographers"*** in the learning space, mapping out logical and analytical relationships between topics. They know the common pitfalls, misconceptions, and difficulty levels within the content — like knowing shortcuts, dead-ends, and the safest or fastest routes. However, preparing personalized routes for every learner is usually unfeasible due to limited expert resources. As a result, **experts design a generalized learning path based on assumed parameters for a "common learner" profile.**

Learners are no longer bound by this pre-determined linear path thanks to the new-generation of AI systems. **It is now possible to start learning from any point within the instructional content and make non-linear progress.**

"Breaking the Linear Progression"

For instance, consider a company designing a training program on "Conflict Management." Typically, it would start with basic concepts like defining conflict, its causes, and types, then move on to advanced topics like conflict resolution strategies. In a conventional approach, learners must follow this order. In an AI-supported learning experience, however, if a learner already understands the basic concepts, they can skip directly to conflict resolution strategies. Or, if their focus is on understanding common conflict scenarios, they can jump to that section.

This type of **“jumping”** or **“teleportation”** in the learning space is **more possible and efficient than ever**. In the past, non-linear navigation relied on instructional designers partitioning content meaningfully, allowing learners to switch between different videos, pages, modules or documents based on titles or descriptions. At most, learners could run a lexical search to match specific keywords to find the content chunk of their interest. **But they lacked a high-resolution map of the entire learning space.** Now, with large language models **(LLMs)** and methods like Retrieval-Augmented Generation **(RAG)** or **semantic search**, learners can find precise locations in the learning content. **They can express their needs or preferences in natural language, and AI systems can determine the most relevant points in the content to meet those needs.**

However, **the ability to teleport in the learning space alone does not guarantee a productive learning experience.** We don’t want learners to get lost or overwhelmed. When they bypass the pre-determined content order, it’s possible that they might miss critical context or connections, leading to confusion. After all, there are valid reasons for the sequencing of learning content. In this case, **the learner would traditionally turn to experts or instructors. But, as noted earlier, these resources are limited and cannot always be available.** This is where AI comes in — not just enabling teleportation but also providing navigation at all times.

AI-powered learning assistants can act as personal guides, ensuring learners stay on track. If learners become overwhelmed or notice gaps in their understanding after jumping to a new section, they can consult the AI for clarification or be directed to relevant points to fill those gaps. To put this in concrete terms: learners can now start engaging with content at the level and from the perspective they are most comfortable with. They can step back if necessary or speed up if they feel confident. The best part? The new generation of AI systems can fill in for personal instructors or experts, ensuring continuous support. New technologies open up a brand-new type of learning experience by bending the spatial dimension of the learning space. Learners can now follow unique, non-linear paths to reach their learning goals.

2. TIME

In classical instructional design, a significant assumption is made about the learner: **"You need to acquire this set of knowledge and skills for your profession or for situations you may encounter in life."** We tend to overlook the fact that this is a bold presumption. Often, we are expected to learn things **"just in case"** we need them later. But what if we could learn exactly what we need, right when we need it? This would create a far more efficient and effective learning experience.

This idea, known as **"Just-In-Time Learning,"** has been around for some time. It's an objectively better approach, as it teaches people what they need to know when they actually need to know it, instead of overloading them with information they might never use. However, implementing this approach effectively has always been challenging — until now.

Artificial intelligence technologies have the potential to bend the learning space in terms of time, making it possible **to access the right content and resources exactly when needed,** resulting in a more meaningful and novel learning experience.

"Breaking the Temporal Linearity"

A relatable example can illustrate how bending the time dimension works in practice. Imagine an employee who needs to learn how to use a new software tool. In the traditional model, the employee would attend a pre-scheduled training session or enroll in a digital video series covering all the tool's features. **But much of this information might be irrelevant at that moment, and the employee could forget most of it by the time they actually need it.**

In an AI-supported system, however, **the employee could access the necessary information at the precise moment they need it — while they are using the software.** They could receive instant answers to their questions, follow step-by-step guides, or practice through interactive tutorials using chatbots, virtual assistants, or smart search features. For instance, if all they need is to update a record, they wouldn't have to sit through an explanation of the user interface or authentication steps they already understand. Instead, they could simply ask the AI assistant for instructions on updating a record, and that would be enough.

Recent advancements in Generative AI, particularly in natural language processing (NLP), computer vision, and speech recognition and speech synthesis, have made just-in-time learning more feasible than ever.

Learners can now interact with content in natural and intuitive ways, focusing only on what is immediately relevant. Large language models can interpret learners' questions and generate context-aware, personalized responses. The ability to input images or videos allows learners to express their problems more richly, while speech recognition and speech synthesis enable voice-based interactions with virtual assistants, making it possible to learn even while multitasking or on the move.

Furthermore, AI algorithms can learn from user interactions, identifying frequently asked questions and continuously optimizing content delivery. These developments have the potential to transform just-in-time learning from an idealistic notion into a practical reality. When learners can choose when to engage with specific content, it marks the first true step toward personalized learning experiences.

3. FORM

Another key component of the learning experience is **the form in which we learn, referring to the format of learning materials.** Learning content can take many forms — videos, podcasts, books, infographics, SCORM packages, and more. **Although the primary focus of learning is on acquiring knowledge and skills, instructional designers often spend much of their time managing these forms and formats.**

Creating content is a **costly process,** requiring time, expertise, and financial resources. In the learning space, this is a highly demanding endeavor **in terms of energy consumption.** Typically, considerable efforts put in determining the appropriate format for given learning objectives, only then the content is produced. Once produced, however, we become tied to that format. Turning an existing instructional video into a PDF document introduces additional cost on top of the video's initial production. Converting a podcast into a visual presentation is time-consuming.

Although the learning objectives are supposed to dictate how the delivery should happen, the format and convenience often constrain learning experiences. We are forced to stick with whatever vehicle is provided for a particular destination.

"Form Alterations in the Bent Space"

Fortunately, this is beginning to change. Generative Artificial Intelligence technologies are making it much easier to transition content between different formats. It is becoming increasingly feasible and efficient to reproduce existing content in the learner's preferred format or to suit their specific constraints.

For example, a sales training video can be transformed into a podcast, a job aid, or an interactive presentation using Generative AI tools in exchange of acceptable resource allocation. This enables the same content to be adapted to different learning preferences and needs.

In addition to addressing individual differences, this flexibility allows for adaptation to physical or temporary constraints. Consider someone with a tight travel schedule who would find it difficult to follow a traditional e-learning course featuring several videos and section. But they could easily listen to bite-sized podcast episodes while on the move.

In this evolving learning space, learners no longer need to worry about the configuration or limitations of the “vehicle” they use to reach their learning goals. **Instead, they can switch between formats effortlessly and focus solely on the journey of learning itself.**

PSYCHOLOGY OF THE LEARNER IN A BENT SPACE

The transformation of the learning space through artificial intelligence is likely to have profound psychological effects on learners' **motivation, self-efficacy, and engagement.**

One-size-fits-all learning approaches often lead to frustration and disengagement as they overlook individual needs and preferences. In contrast, AI-powered personalized learning caters to each learner's unique characteristics, fostering more positive emotions and attitudes toward the learning process. Even though this very comparison is frequently being advocated, it generally happens without taking the next step to elaborate on how this would take place in the real world.

Now, let's try to explain how specific aspects of AI enabled personalization and adaptiveness are related to said psychological constructs.

For example, allowing learners to progress at their own pace, in a manner that suits their specific needs, enhances their sense of self-efficacy and control. This increased autonomy builds confidence, making learners feel more capable of succeeding and progressing. Furthermore, content tailored to their interests and priorities sustains motivation and curiosity, **encouraging deeper emotional investment and commitment to the learning process.**

AI systems can also enhance **satisfaction and retention** by providing instant, personalized feedback. Traditional learning methods often offer delayed and generic feedback, which can fail to address individual learning gaps. With AI, learners can receive real-time performance assessments, enabling immediate identification of learning gaps and tailored recommendations for improvement. This instant, precise feedback boosts learners' motivation to continuously improve.

Moreover, AI can increase emotional engagement by making the learning experience more enjoyable and interactive. We know that gamified elements, interactive activities, and well-timed breaks can all enhance engagement, **but effectively orchestrating these elements is challenging.** New AI systems are improving in their ability to monitor learners' progress and psychological state which is likely to help introducing these elements at just the right moments to keep learners engaged and motivated.

The psychological benefits of AI-supported learning illustrate how this technology not only address learners' cognitive fun but also nurtures their emotional well-being. By leveraging AI, organizations can create a more effective and sustainable learning culture that actively addresses learners' motivation, attitudes, and current levels of understanding.

THE ROLE OF THE INSTRUCTOR IN THE BENT SPACE

The bending of the learning space by AI significantly impacts not only learners but also teachers and instructors. Traditionally, teachers have long been seen as the primary source and transmitter of knowledge. Although modern education calls for a shift in the instructor's role toward being a guide, facilitator, and mentor, this shift has often been more theoretical than practical. The gap between the desired role of instructors and the reality of traditional education models has been difficult to close.

However, when instructors are empowered with the tools to bend the learning space through AI, they can truly embrace the facilitator role. In a flexible learning environment, the route, timing, or method of instruction becomes secondary to understanding and confirming the learner's progress. This shift creates a more dynamic and responsive learning experience, where the instructor can focus on guiding learners through their journeys rather than adhering to rigid curricula or schedules.

With these tools, instructors can delegate the task of direct knowledge transfer to AI systems while maintaining supervision over the learner's path. **This delegation does not diminish the instructor's importance; rather, it enhances their role by allowing for more meaningful interactions and interventions.** AI systems can handle repetitive, logistical tasks, freeing instructors to focus on higher-level functions like assessing learner progress, providing personalized guidance, and addressing individual needs. This collaboration between instructor and AI can lead to more efficient use of time and resources, ultimately improving learning outcomes.

To fully embrace this evolving role, instructors need to develop new skills and competencies. A basic understanding of AI technologies is essential, as is the ability to work effectively with AI systems to design and facilitate learning experiences. This requires a mindset shift, with instructors becoming comfortable interpreting AI-generated data and using these insights to inform their teaching strategies and interventions.

The good news is that instructors themselves can benefit from AI-enhanced learning environments. **By bending their own learning spaces, they can become better "guiding stars" in their learners' educational journeys.** This self-directed learning and adaptation exemplify the power of the bent space concept, not just for students but for educators as well. Instructors can be equipped with a deeper understanding of how to integrate these tools into their teaching through experiencing firsthand the benefits of AI-supported learning.

As education continues to evolve in an AI-enhanced landscape, **the balance between technological innovation and human touch is crucial.** While AI can handle much of the knowledge transfer and technical skill development, the human role in providing emotional support, fostering critical thinking, and nurturing creativity remains irreplaceable. The challenge lies in blending AI assistance with human guidance to create truly transformative learning experiences.

MATERIALIZING THE LEARNING SPACE: IT IS A REAL THING NOT JUST A METAPHOR

Before concluding my discussion on "Bending the Learning Space with AI," I would like to address one final point.

As I've outlined earlier, the learning space is a conceptual framework designed to help explain the potential impact of AI on learning experiences in an analytical and visual way. On the surface, it might seem like a metaphorical construct to illustrate AI's capabilities in improving learning. However, this idea goes beyond mere metaphor. It is possible to build an actual learning space where learners can navigate and progress.

Let me explain.

Transformer-based models do not simply generate new sequences of data; **they are also exceptionally good at understanding existing data.** A particular class of neural networks called "**embedding models**" is crucial for this. Embedding models transform various types of data—such as text, audio, and visuals—into vector representations within a "**feature space**"

However, this feature space is not yet the "learning space." The feature space organizes data points based on their semantic relationships, which is important for learning but insufficient by itself. Not all semantically close data points are relevant for a specific learning goal.

For example, consider a biology class with the following objective:

"The learner is expected to clearly state the differentiating features between living organisms and non-living things."

In a feature space, the words "livelihood" and "living" might be placed very close to one another due to their semantic similarity. Similarly, the phrase "living organisms respond to stimuli" might be close to "the livelihood of an organism is tied to healthy social interactions." However, from a biology curriculum perspective, the latter examples are irrelevant and need to be placed far apart in the learning space.

To move beyond a raw feature space and create a true learning space, **we need two additional components: large language models (LLMs) and graph networks.**

Graph networks are efficient for representing data as nodes (representing key concepts) and edges (representing relationships between those concepts). Without diving too deep into the technical details, I will simplify how these components can work together.

Embedding models help "understand data" by mapping semantic relationships, while large language models help "understand language" to generate meaningful responses. Together, they can identify significant pieces of information (nodes), their relationships (edges), and how these can be grouped into higher-level concepts. This process allows us to build **a graph network that represents the learning space, where nodes represent learning objectives or concepts and edges represent possible pathways between them.**

With this setup, we can input raw learning content and objectives, and the system can generate a learning space that closely aligns with the principles discussed earlier:

Learners can then follow these edges (paths) to move from one level of knowledge or skill to the next. The process of teaching a particular set of nodes requires resources — what we've termed "energy." Learning materials can encapsulate several nodes, guiding the learner through the graph network, i.e., the learning space.

Additionally, learners can navigate this graph network efficiently, using keyword searches, natural language queries, or similarity searches based on the statistical relationships within the graph. This allows instructional designers to create environments where learners can "teleport" to relevant nodes whenever necessary—just in time.

I recommend **experimentation with this pipeline to create learning spaces from content data**, refining best practices for streamlining the process. While this approach is highly technical, once established, it can be optimized to generate numerous learning spaces, enhancing the utilization of AI for better learning experiences.

I'd like to conclude by **encouraging collaboration between AI experts and instructional technology specialists.** From my own work, I can confidently say that this approach has yielded significant results. **Several AI-supported learning tools and features built on these learning spaces are already in use.** This method has proven promising for both understanding AI's impact on learning and implementing meaningful, real-world applications.

Bending the Learning Space with AI | Materializing the Learning Space

Bending The Learning Space with Artificial Intelligence

A framework to understand the impact of new generation AI systems on learning experience.