A Cybernetic Perspective on Generative AI in Education: From Transmission to Coordination

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Abstract

The recent sudden increase in the capabilities of Large Language Models (LLMs), and generative AI in general, has astonished education professionals and learners. In formulating a response to these developments, educational institutions are constrained by a lack of clarity concerning human-machine communication and its relationship to models of education. Ideas and models from the cybernetic tradition can help to fill this gap. Two paradigms are distinguished: (1) the transmission paradigm (combining the model of learning implied by the instruments and processes of formal education and the conduit model of communication), and (2) the coordination paradigm (combining the constructivist model of learning and the coordination model of communication). It is proposed that these paradigms have long coexisted in educational practice in a modus vivendi, which is disrupted by LLMs. If an LLM can pass an examination, then from within the transmission paradigm this can only understood as demonstrating that the LLM has indeed learned and understood the material being assessed. At the same time, we know that LLMs do not in fact have the capacity to learn and understand, but rather generate a simulacrum of intelligence. It is argued that this paradox prevents educational institutions from formulating a coherent response to generative AI systems. However, within the coordination paradigm the interactions of LLMs and education institutions can be more easily understood and can be situated in a conversational model of learning. These distinctions can help institutions, educational leaders, and teachers, to frame the complex and nuanced questions raised by GenAI, and to chart a course towards its effective use in education. More specifically, they indicate that to benefit fully from the capabilities of generative AI education institutions need to recognize the validity of the coordination paradigm and adapt their processes and instruments accordingly.

Keywords

I. Introduction

THE recent sudden increase in the capabilities of Large Language Models (LLMs) and other generative artificial intelligence (GenAI) applications has astonished education professionals and students. A wide-ranging debate has emerged concerning the immediate and future impact of these developments on educational institutions and practice, focusing on topics such as assessment, the role of the teacher, the opportunities for students, and the implications for institutions.

The present paper contributes to the clarification of this discourse in the context of formal education. The core activity of education is communication between humans, often mediated by texts and other media, in conversations between actors that include students, teachers, administrators and policymakers. It is therefore hard to achieve clarity in the understanding of the impact of AI on education without a clear understanding of the nature of human-machine communication. The present lack of consensus on how GenAI could or should be used in education, and whether its use is constructive or destructive, suggests that this understanding remains problematic. This paper proposes a historical perspective on thinking about models of communication and learning, largely associated with the cybernetic tradition, which has renewed relevance in helping to navigate the complex terrain presented by generative AI and education. We summarize the conclusion of each section in a brief text in italics, to provide an overview of our argument. We commence with a brief review of the technology under discussion.

II. State of the Art

Generative modeling, also known as GenAI or generative AI, leverages unsupervised learning techniques such as Generative Adversarial Networks (GANs) and Variational Autoencoders (VAEs) to discern patterns in various types of content, ranging from text and images to video. By doing so, it gains the ability to create new content that mirrors these identified patterns. Within text, this technology manifests as Language Models (LMs) and their extensive counterparts, Large Language Models (LLMs). The primary distinctions between these two lie in the scale of data used for training — LMs typically

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utilize smaller, domain-specific datasets, whereas LLMs draw from vastly larger data pools — and their respective use cases, with LMs being more suited for tasks like text prediction and spell checking, and LLMs being designed for text generation.

In this context, transformers, and in particular generative pre-trained transformers (GPT), are the de facto standard to implement LLMs. GPT uses large amounts of text data to create a generative model that captures and replicates the structure of a phrase. As a result, LLMs can process and produce human-like text outputs and open the door to a variety of educational applications.

In this brief review we focus on the most recent applications of LLMs in education. García-Peñalvo and Vázquez-Ingelmo [1] characterize the generative AI landscape, while Zhao *et al.* [2] provide a survey of the underlying technology of large language models. A number of overviews of applications and limitations in educational settings are available [3] [4] [5] [6]. Table I presents examples of generative AI applied to education published in 2023, focusing on the LLM used and the input data. Although LLMs have the potential to be applied to any area of knowledge, applications to date have tended to focus on specific areas like coding and math. We identify five main applications, namely: (1) Automatic Grading; (2) Exam Solution; (3) Educational Content Generation (including tests); (4) Plagiarism Detection; and (5) Tutoring. Other reviews have proposed a higher number of groups in the classification [5] [3].

TABLE I. Generative AI Applications for Education, Including Application, LLM Model Used and Data

Ref.	Application	LLM	Data
[7]	Grading	OpenAI GPT-3	Computer Sci. Exams
[8]	Grading	OpenAI GPT-4	Questionnaire
[9]	Exam Solution	OpenAI GPT-4	Law Exams
[10]	Plagiarism	OpenAI GPT-3	Math Exams
[11]	Tutoring	OpenAI GPT-3	Math Exercises
[12]	Tutoring	OpenAI GPT-3	Word Vocabulary
[13]	Tutoring	GPTeach	Course data
[14]	Test Generation	OpenAI GPT-4	Questionnaire
[15]	Exam Solution	OpenAI GPT-3.5	High School Exams
[16]	Plagiarism	OpenAI GPT-3.5	Human/GPT Texts
[17]	Content Generation	N/A	Python Code
[18]	Content Generation	OpenAI Codex	Python Code
[19]	Exam Solution	OpenAI GPT-4	Medical Exam
[20]	Exam Solution	OpenAI GPT-4	Physics Exam
[21]	Exam Solution	OpenAI GPT-3.5	Medical Exam
[22]	Tutoring	OpenAI GPT 3	Questionnaire

Although there is a variety of LLMs available, both commercial (OpenAI ChatGPT, Bing, etc.), and open source (Llama, Llama2, BLOOM, Alpaca, PaLM2, Bert and its variations, DeepMind Gopher, etc.), ChatGPT has become the standard to implement educational research studies. The use of other LLMs in recent studies seems to be residual. From the examples presented in Table I only one work [13] proposes its own LLM, called GPTeach, but even in this case it uses ChatGPT-3 API for solving questions. This contrasts with the results observed in another study [5] where Bert (and its variants) was used in almost 90% of the studies up to 2022, and ChatGPT in all its versions was used marginally. As a result, the study claims that the most advanced LLMs models have not been the focus of educational tasks. This is not the outcome of other review papers [3] [4] that conclude that ChatGPT-3, which at the time was the most advanced, was being widely used for educational applications. In any event, Table I indicates that current studies are based on the most advanced LLMs implementations such as ChatGPT 3.5 and ChatGPT4.

Current educational applications are largely built using commercial LLMs, although there is a wide range of open source LLMs. This is mainly because of the complexities and cost of training open source LLMs. Commercial implementations (e.g. GPT-4) have been already fine-tuned for conversation (e.g. ChatGPT-4), and the use of this foundation makes it possible to focus directly on the relevant research questions and possible applications. This approach has its drawbacks as there is no control or detailed knowledge over the data used to train the LLM. In contrast a fully open model opens the door to difficult questions about the legality and quality of sources. Fine-tuning of pre-trained LLMs with smaller and more specific datasets that are adapted to a particular domain is less problematic and enables the personalization of learning materials. Following this approach ChatGPT-4 is already being deployed in learning applications such as DuoLingo [23] for learning languages or Khan Academy [24] for personalized learning.

LLMs have the potential to affect the whole educational community, but the papers we have examined show that the focus to date has been on educators/teachers and students. The use of LLMs for other stakeholders such as academic administrators or policy makers seems to be residual, or undocumented, and still needs to be explored. However, the rapid transformation of workplaces through the application of AI [25] raises many open questions about the future of academic management and leadership. Concerns have also been raised about bias in AI applications [26], and their compliance with ethical standards [27], raising a large number of additional open questions.

Table I highlights the recent impact and potential of LLMs (mainly of ChatGPT) for educational applications. Nevertheless, there are many concerns and limitations including: (1) data privacy, (2) bias of generated content (especially regarding the language used [26]); and mainly (3) the potential impact on educational practice. Most of the studies do not evaluate the impact of the application in an educational setting. There are some exemptions, mainly when the application is exam solution as it can be directly compared with previous results [9] [19] [20], and in some cases content generation, for example a study [17] that concludes that the perceived quality of AI-generated resources is largely on par with student-generated resources. In general, it is difficult to ascertain the actual benefits and limitations of the five application areas identified in pedagogical settings.

A key thread of research concerns the degree to which LLMs improve the engagement of students in the learning process, hypothesized improvements comprehension, retention, and overall academic success [28]. Progress on this topic requires not only rigorous experiments, but also increased clarity on the nature of human-machine communication and its implications for education, which is the issue we address in this paper. It can be seen that much valuable research is being carried out into the use of LLMs in education, but this work tends to focus on the results of introducing the technology into an educational activity, without examining the processes involved in human-machine communication. Moreover, we note that the reviewed studies investigate the integration of LLMs in education without using theories of communication and learning as a backbone of their research. This makes it hard to compare like with like, or to cumulate research results.

At the heart of education is the interaction between students, teachers and learning resources. It is therefore unsurprising that a lack of clarity about what is happening during communication between humans and machines generates uncertainty among education professionals and institutions about the position they should adopt when faced by GenAI in general and LLMs in particular. In the discussion below we propose some theoretical tools which can assist in inspection and analysis of interactions between GenAI and

educational actors, and which provide a framework within which educational policy can be formulated.

There is huge interest in the potential of GenAI in education, and an extensive body of evidence. However, there is a lack of clarity on the nature of the educational interactions which GenAI supports.

III. Two Views of Learning

In most formal education, the design of organizational processes assumes that knowledge can be delivered by a teacher or an institution to a student. This assumption is embedded at all levels of the education system: in national plans, curricula, quality assurance processes, teaching plans, and not least in the fees charged for access to courses. A particularly clear example is the field of knowledge management, which is built on the ideas of capture and delivery of knowledge (see Girard and Girard [29] for an overview).

In contrast, the practice of teaching has been strongly influenced by the constructivist theory of learning. We cannot here provide a detailed account of the many ways in which constructivism has been conceptualized, applied, and critiqued, but the following examples indicate its scope. In his influential 'Radical Constructivism: A Way of Knowing and Learning', von Glasersfeld [30] starts his discussion with the sceptics of ancient Greece, but more conventionally the tradition is traced back to Vygotsky and Piaget, with further development being carried out by a host of psychologists, philosophers and educationalists, including Jerome Bruner, Paolo Freire, Seymour Papert and Gert Biesta. The last of these has written that:

> The founding intuition of constructivism is that knowing and learning are processes in which knowers and learners actively construct their knowledge and understanding – they make sense – rather than that this should be understood as a process where knowers or learners passively receive such knowledge and understanding. [31]

Constructivism is a theory of learning, and it has been accompanied by theories of pedagogy, notably those known as Learner Centered Pedagogy, which has been widely influential among teachers. Bremner, Sakata and Cameron recently conducted a systematic review of the outcomes of Learner Centered Pedagogy (LCP) [32] which concludes that "there is a real gap in hard data to prove or disprove the value of LCP", while teachers and students "lean towards positive experiences of LCP".

Individual teachers and theorists may be convinced constructivists or may vehemently oppose constructivist ideas. At the level of the education system, however, the two contradictory views have cohabited for half a century. On the one hand, the organizational instruments of the education system (such as curricula, learning objectives and lesson plans) assume that it is possible to prescribe what students will learn, how they will learn it, and how long this will take. On the other hand, many teachers are strongly influenced by a belief that the characteristics, prior experiences and activities of students determine what they learn and how fast they learn it, with profound consequences for their classroom teaching practice and informal interactions with students. These two contradictory positions have resolved to a *modus vivendi* which enables educational activities to proceed smoothly. Part of the explanation for this coexistence is that the two theories of learning do not generate mutually exclusive classroom activities. In this context, Richardson points out that "students also make meaning from activities encountered in a transmission model of teaching such as lectures or direct instruction, or even from non-interactive media such as television". As a result, the coexistence of the two models of education is often not commented upon, or even not perceived. The balance between the two varies from one place to another and adjusts over time, responding to changing patterns of teaching practice and to the shifting winds of political and social pressures. In the following sections, we discuss two models of communication which are compatible with the two conceptions. These are not the only two available models of communication, and they have nothing to say about the emotional or dialectic aspects of communication. However, we argue that they are of great utility in understanding the communication between humans and machines.

The transmission and constructivist models of learning coexist in educational practice, in a long-standing modus vivendi.

IV. Two Models of Communication in Education

A. The Transmission Model of Communication

The conception of the communication of knowledge underlying the organizational structures of education has close parallels to Shannon's mathematical model of the transmission of information (Fig. 1), which was published in 1948, but nevertheless remains a cornerstone of the teaching of telecommunications. Weaver, who collaborated closely with Shannon, explicitly stated that "...information must not be confused with meaning. In fact, two messages, one of which is heavily loaded with meaning and the other of which is pure nonsense, can be exactly equivalent, from the present viewpoint, as regards information." Nevertheless, there has been confusion about the relationship between information and meaning implied by the theory since its formulation. Indeed, misinterpretation is hard to avoid given the lack of precision in English vocabulary. For example, as Reddy pointed out, the word 'message' used in Shannon's model is ambivalent in English, referring to both the means of communication "I got your message (MESSAGE1) but had no time to read it" and also the understanding of the recipient "Okay, John, I get the message (MESSAGE2); let's leave him alone" [33].
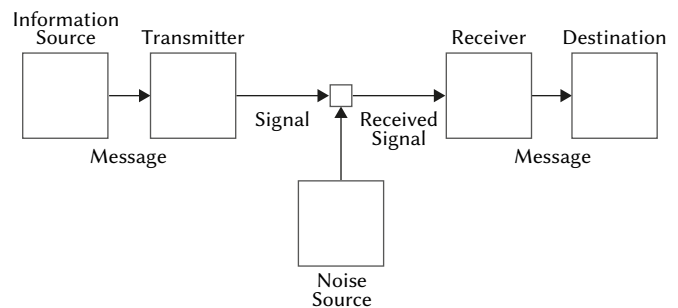

Fig. 1. Shannon's "Schematic diagram of a general communication system", adapted from [34].

In 1979, Reddy characterized the merging of these two meanings of 'message' as the *conduit metaphor*, which sees language in the following terms: "(1) language functions like a conduit, transferring thoughts bodily from one person to another; (2) in writing and speaking, people insert their thoughts or feelings in the words; (3) words accomplish the transfer by containing the thoughts or feelings and conveying them to others; (4) in listening or reading, people extract the thoughts and feelings once again from the words." There are, of course, other metaphors for communication. Krippendorff [35] (p.51-70) distinguishes five metaphors for communication in addition to the conduit metaphor: hydraulic, control, transmission, war, and dance-ritual. The first three of these, however, are largely compatible with the conduit metaphor. Moreover, for our present purposes, the importance of the conduit metaphor is that it maps closely onto the aspiration of education to deliver knowledge to the student, and the implied assumptions of its organizational processes.

Pace Weaver, the Shannon / Weaver diagram can be used (or abused) to represent the conduit metaphor, and mapped onto educational processes, as shown in Table II.

TABLE II. The Conduit Model Mapped to Education

Information source	A teacher, a video recording, an author, a work of literature, a data set, etc.
Transmitter	A teacher's speech and activities, a copy of a book, a journal paper, etc.
Noise Source	Disturbance in the classroom, students' psychological states, inadequate or faulty equipment, etc.
Receiver	The student (identical with the destination), a computer
Destination	The student

The productive activities of a student can be described in a similar way, as shown in Table III. The model, if accepted as accurate, also functions as a tool for apportioning blame for failure: if a student's achievement is not satisfactory, then the problem can be sought in one of the steps. So, for example, the teacher's transmission of the information may be inadequate, or the classroom environment may be dysfunctional, or the student may not be listening. Certain approaches to educational technology are often (though not necessarily) aligned with the conduit model. Examples of how researchers are integrating machine learning and GenAI methods with them include competence management systems [36], recommender systems [37], and knowledge management [38].

TABLE III. The Conduit Model Mapped to Students' Activities

Information source	The student
Transmitter	An essay, assignment, multiple choice test, *viva voce,* etc.
Noise Source	Poor language and writing skills, student's psychological states, noisy environment, inadequate or faulty equipment, etc.
Receiver	The teacher
Destination	The educational institution

B. The Coordination Model of Communication

The biological theory of communication put forward by Maturana and Varela in the 1980s is based on coordination rather than transmission. We briefly summarize it here, but the theory is complex, and readers are advised to engage with the original exposition, most accessibly presented in the book 'The Tree of Knowledge' [39]. We summarize Maturana and Varela's view of communication as follows:

1. Organisms are organizationally closed but structurally open, i.e. organisms have a standard biological plan which is inherited and fixed, but they grow, think and act in different ways in interactions with the environment.

2. Organisms respond to perturbations in their environment with neuronal activity, but in this process, nothing enters the organism from outside.

3. Organisms become structurally coupled to their environment, i.e. a history of recurrent interactions leads the organism to adjust to its environment, and vice versa.

4. Other organisms are part of the environment. Organisms structurally couple to each other, each adjusting its internal structure in response to the actions of the other. These coordinations constitute communication.

5. Humans use sounds, letters, images and movements to coordinate their coordination. For example, we have learned from prior interactions to associate the sound and written form of the word 'baby' with a young human. This higher-level coordination constitutes language (or as Maturana and Varela would prefer 'languaging').

Maturana and Varela "...conclude that, biologically, there is no "transmitted information" in communication", and argue that the conduit metaphor "is basically false" [39] p196. From this perspective, the processes of education should be seen as an ongoing structural coupling between teachers and students, mediated by a wide range of language-based activities. Through these recursive coordinations, the structure of the student changes, and they become able to perform the tasks required of a successful student. Approaches to educational technology that are often (though not necessarily) aligned with the coordination model, and where work is underway to integrate AI, include computer supported collaborative learning [40], self-regulated learning [41], and the use of writing productivity tools [42]. Beyond these, however, lies the largely unmapped terrain of students' informal interactions with GenAI, which has consequences for students coordinations with teachers and institutions that have not yet been fully manifested, let alone understood.

We refer to the combinations of the respective models of educational processes and of communication as the 'transmission paradigm' and the 'coordination paradigm'. GenAI

The transmission and constructivist models of learning are congruent with the conduit and coordination models of communication.

V. Generative AI: A Paradox for Education

The coexistence of the two conceptions of education that we have described in Section IV.A and IV.B is radically disrupted by generative AI in general and LLMs in particular. Yeadon et al. write that "short-form essays, written by AI software in only a few seconds, can score a First Class for an assignment from an accredited university Physics module. This, we argue, effectively renders the short-form essay obsolete as an assessment tool." [43] The abilities of current AI should not be overstated, as it falls short in some full examinations. While it was successful in radiology [44] it failed in plastic surgery [45] and in the sixth-grade math and science examinations in Singapore [46]. However, the capabilities of AI will only increase, and as Eulerich *et al.* report [47], ChatGPT 4 can pass exams which were too demanding for ChatGPT 3.

The ability of GenAI technology to create acceptable student texts is a practical problem for education, but the challenge is not unprecedented. As Sharples points out "Transformer AI systems belong to an alternative history of educational technology, where students have appropriated emerging devices – pocket calculators, mobile phones, machine translation software, and now AI essay generators – to make their lives easier. The response from teachers and institutions is a predictable sequence of ignore, resist, then belatedly accommodate." [48] Nevertheless, GenAI presents a different and deeper challenge than the technologies, which Sharples mentions. This is because it can disrupt the equilibrium which has developed between the organizational processes of education and the constructivist practices of teachers, corresponding to the transmission and coordination models of communication.

Education institutions use the performance of students in examinations as evidence of whether students have learned and understood the content of a course or not. According to the transmission view of communication, the information which is extracted at the destination is the same as that which was

transmitted by the information source. Consequently, according to the transmission model of education, in combination with the use of the examination as an assessment instrument, the ability of a GenAI to create texts which merit a pass in an examination must mean that the system, which generates them texts, has knowledge and understanding which matches that of the students who pass the same examinations. However, as we discuss in the next section, there is strong evidence that this is not the case. Education institutions are therefore confronted with a paradox: their educational instruments tell them that LLMs are intelligent learners, but the research evidence and close engagement with GenAI systems shows that LLMs are not intelligent learners. Without resolving this paradox, educational institutions cannot formulate a coherent response to GenAI systems.

Generative AI creates a paradox for the transmission model of education.

VI. What Does Generative AI Generate?

Some have argued that AI systems do indeed have human level knowledge and understanding, including Blake Lemoine, a Google software engineer working on AI, who was fired in 2022 for maintaining that the system he was working on was conscious [49]. To many others with close knowledge of GenAI, these claims seem intuitively absurd. That is not a sufficient refutation, however, and it is important to establish a stronger argument against ascribing human level capabilities to GenAI.

Gregory Bateson, like Maturana and Varela, worked within the cybernetic tradition, and he thought deeply about the nature of mind and machine. In an earlier paper we have discussed in detail the implications of his work for AI [50], and here we summarize two of his arguments which imply that we should not ascribe human-like mental states to present-day computers.

Firstly, Bateson argues that "The question is not "Can machines learn?" but what level or order of learning does a given machine achieve?" [51] (p.284). Bateson's *Level I learning* involves changes in the responses which a machine or organism gives at different times, possibly as a result of habituation or reinforcement. This level of learning is displayed by LLMs. *Level II learning* involves 'learning to learn', for example as one might improve one's ability to learn musical scales not by continual practice but by a change in learning strategy. The term 'deep learning' refers to the depth of layers of neural networks but gives the impression that AI can learn in a more than superficial way. It is true that LLMs have moved AI closer to *Level II*, to the extent that stochastic changes lead to improved algorithms. However, this takes place within a tightly constrained and fixed framework. There is no equivalent in deep learning to the developmental changes that take place when a student acquires an entirely new body of knowledge or skill, transforming the way they go about solving problems and thinking about the world.

Secondly, Bateson argued that information flow takes place within an 'ecology of mind'. In his view, mental processes include "a number of phenomena which most people do not think of as processes of thought" [52] p.16, including embryology, evolution, and "all those lesser exchanges of information and injunction that occur inside organisms and between organisms, and that, in the aggregate, we call life." [52] p.17. This ecology of mind "...will usually not have the same limits as the 'self'" [51] p.317, and includes both animate and inanimate entities. A computer is not equipped with the sensors and effectors, nor the mental processes which are required to create the rich set of interactive loops between itself and the outside world which constitute an ecology of mind. In other terms, it is not embodied, in the sense that Varela, Thompson and Rosch describe: "...

first, cognition depends upon the kinds of experience that come from having a body with various sensorimotor capacities, and second, that these individual sensorimotor capacities are themselves embedded in a more encompassing biological, psychological, and cultural context." [53] (p.173).

More recently, Brian Cantwell Smith has argued along similar lines that all AI systems, including GPTs, literally "do not know what they are talking about" [54] p.76. "...there is no reason to suppose, and considerable reason to doubt, that any system built to date, and any system we have any idea how to build, 'knows' the difference between: (i) its own (proximal) state, including the states of its representations, inputs and outputs; and (ii) the external (distal) state of the world that we at least take its states, its representations and those inputs and outputs to *represent*." AI is able to perform extraordinarily complex manipulations of words and their tokens, and to relate them to each other. But AI does not know that there is a world external to itself, or that its representations are about that world, and it cannot take responsibility for the adequacy of its representations to describe the world [54] p.79. Consequently, when an AI system produces a student essay about, for example, preserving the rain forest, it cannot 'know', in any way that is equivalent to human knowing, what a forest is, nor why it might have importance. It can provide only reports on correlations among its internal states. In this sense, AI systems are electronic solipsists, whose processes correspond to Bradley's characterization of solipsism as the belief that "nothing beyond my self exists; for what is experience is its states" [55] p.248.

These arguments lead us to conclude that a text produced by generative AI is a simulacrum of human communication which, as Baudrillard put it "itself, no longer even knows the distinction between signifier and signified, nor between form and content". [56] p.63-64.

Generative AI generates a simulacrum of human intelligence.

VII. The Implications of AI Simulacra for Education

Consider a trap deployed to attract and snare a pest species, for example Zapponi *et al.* [57] describe how pheromones and vibrations are used for to capture stink bugs. In terms of the conduit model, the sense organs of the insect are the *receiver* of information, and the insect itself is the *destination*. The bug perceives the pheromones and vibrations as a signal whose *transmitter* is the organs of a fellow bug, and the *information source* as a potential reproductive partner. But the bug has been tricked, the information source is in fact a device which generates a simulacrum of a reproductive partner, and the bug has no way of detecting the deception.

An educational institution finds itself in a precisely parallel situation when confronted by examination scripts or essays authored by LLMs: the scripts draw humans into inauthentic interactions with a device. When the assessors of exam scripts award a pass mark to a text produced by AI, they are misled into ascribing to the perceived *information source* knowledge and understanding which is not present. It is axiomatic to the transmission model that learning is contained and transmitted within documents. Consequently, from within this model, an LLM's success in passing an examination can only understood as demonstrating that the LLM which is the source has indeed learned and understood the material being assessed. Like the target of the pheromone trap, the institution has no way to detect or make sense of the deception from within the confines of a transmission model of educational communication, and cannot abandon the model without undermining the credibility of its own instruments. At the same time, it is also clear that LLMs do not have this ability.

A coordination model of educational communication is better equipped to describe educational interactions with LLMs. The

assessment process is seen to be one more example of the coordination around utterances and documents which establish structural coupling between teachers and students, and through which understanding and knowledge are mutually and iteratively probed. A teacher adopting a coordination model when confronted by an AI script is not dissuaded by the logic of the model from concluding that although the text appears to reflect knowledge and understanding, it does not in fact do so. The teacher and the institution are still challenged by LLMs, as the ease with which inauthentic texts can be generated can disrupt the coordination between teachers and students. It is often difficult to distinguish authentic and inauthentic texts, indeed, as Linardaki reports, on the site "Bot or Not" (botpoet.com) a poem by Gertrude Stein was thought by at least 70% of respondents to have been written by a computer [58]. This is a practical challenge for education seen as a process of coordination, of the same order as those presented by the emergence of calculators and the internet. The same cannot be said for education seen as transmission, which finds its foundational axioms to be threatened, undermining the credibility of grades and diplomas.

The challenge of GenAI for education is thus that it disrupts the balance between the instruments of education (transmission model) and the practice of education (often influenced by the coordination model), by undermining the credibility of the transmission paradigm. If a machine which is widely accepted to be incapable of understanding can pass an examination, we are forced to ask if we can take that examination seriously as a measure of learning and understanding, and if the entire edifice of learning objectives and curricula in fact delivers the learning which it claims to do.

An additional consideration is that the predominant manifestation of AI prior to the emergence of LLMs was the expert system. Expert systems are taxonomic in nature, adhering to explicit classifications. The structure of expert systems corresponds to the taxonomic organization of education, which, for example, subdivides knowledge into disciplines, subdisciplines, curricula, learning resources, etc. Expert systems could reflect these structures, making them easy to apply in education (if not easy to create). Generative AI, however, is not taxonomic, but rather (to use McCulloch's word) "...anastomotic, whereby afferents of any sort could find their way by intersecting paths to any set of efferents, so relating perception to action" [59] p.392. In this sense, the inner workings of a GPT are not inspectable, and it is not possible to say why, precisely, a particular output was generated. This is a poor fit for an education system which is based on the verifiable delivery of taxonomic knowledge and is required to be transparent and answerable for interactions which take place within them.

The simulacrum of intelligence produced by Generative AI creates a paradox for the transmission model of education. The coordination model of education is better able to describe educational interactions with generative AI.

VIII. The Possible Responses of Education Institutions

One possible conclusion from our discussion in section VII would be that formal education is a fundamentally flawed enterprise, and it should be swept away, together with its instruments. We do not take this position. Rather, we propose that the irruption of LLMs, and GenAI in general, means that the *modus vivendi* between the transmission and coordination models of educational communication will have to be revised. The balance has been disturbed and can only be restored by adjusting the relative influence of the two models on the educational process.

We characterize the possible responses of educational institutions to GenAI in terms of three extremes. In practice, it is likely that institutions will not simply adopt one of these models, but rather experiment with aspects of these strategies in parts of the institution.

1. Reject GenAI
- The institution decides that its business model and processes require a transmission model.
- The coordination paradigm, and the practices influenced by the model, are anathematized and suppressed, and replaced with an emphasis on rote learning and reproduction of specified formulations of knowledge.
- GenAI is rigorously excluded as a disruptive force.

This strategy has three drawbacks. Firstly, it prevents teachers from making use of the pedagogical flexibility which the current *modus vivendi* affords, with consequent negative impact on student outcomes. Secondly, it requires increased coercion of teachers and students, with negative consequences for institutional dynamics and recruitment. Thirdly, it prevents institutions from benefiting from the substantial benefits which GenAI can provide.

2. Embrace GenAI to replace teachers.
- The institution observes that GenAI is cheaper than teachers.
- The institution moves all its courses online, run by AI, and fires all its teachers.
- The institution gains competitive advantage by selling its courses more cheaply than institutions that employ teachers.

This strategy has the drawback of failing to recognize the limitations of current GenAI and the consequent fall in the quality of the education offered. It is also vulnerable to a race to the bottom, where all education is provided by large AI companies, and educational institutions as we currently know them disappear.

3. Embrace AI to support teaching and learning.
- The institution recognizes that GenAI has shown that the transmission paradigm is built on unreliable foundations.
- Educational instruments are reconceptualized as supports for education based on the coordination paradigm, and gradually optimizes them for this revised function, with special attention to assessment.
- The crucial role played by teachers in supporting learning and understanding is recognized. Institutional management processes, unique selling points and business models are revised accordingly.
- GenAI is welcomed as a powerful technology which can support the activities of students, teachers, and administrators in many ways.
- The institution prepares itself for a radical transformation of its processes and the roles of teachers and students.

This strategy has one substantial drawback: it requires the institution to expend its time and resources on rethinking what the education it offers consists of, and how it should be managed and marketed. The potential rewards for this effort, however, are more effective teaching and management processes, and enhanced opportunities for learning.

Generative AI can support education in different ways, but to benefit fully from its capabilities education institutions need to recognize the validity of the coordination paradigm and reform themselves accordingly.

IX. The Educational Opportunities Offered By Generative AI

The simulacra produced by generative AI are of great utility in many domains and can be used as the basis for the creation of many potentially useful educational applications. We indicate the scope of the services being offered in the following examples, without offering any assessment of their value.

For students, GenAI services can offer support for self-regulated learning and enhancement of students' autonomy [60]. It can provide

tutoring [61] with recommended learning paths and materials, adjusting them for difficulty and focus; support self-evaluation [62]; provide tools to support the writing process [63].

For teachers, as was the case with earlier waves of educational technology, it is proposed that GenAI services can automate some aspects of their work, saving them time for more important teaching activities. Services include automatic generation of exams and class presentations, as well as automated grading. Indeed services are available that create entire courses [64]. GenAI can create sophisticated games and gamified assessments [65], with a GenAI model being fine-tuned to a topic and then generating game mechanics, including points and a leaderboard that can be used to rank students.

Finally, GenAI can help administrators and policy makers in decision making, as discussed in a recent systematic review [66]. GenAI can also provide administrative support for students, while the company Tribal [67] offers AI driven improvements in admission and enrolment, diversity, timetabling, and predicting and responding to inspections.

The argument made in this paper, however, suggests that success of GenAI in supporting students, teachers and managers will not be determined solely by its technical capabilities and the attractiveness of services such as those discussed above. Its effectiveness will also depend on the ability of institutions to create an environment where people can participate in human-machine interactions in ways which are coherent with the organizational structures and teaching activities of the institution. Gordon Pask, working in the cybernetic tradition, developed a framework called 'conversation theory' [68], which provides a starting point for imagining how such interactions might be applied in learning activities.

Pask saw learning as taking place through interpreted formal relationships, with a student's understanding developing through agreements between the participants in a conversation, typically involving a teacher and a student. To support this conversation, Pask argued that it is "necessary to develop a network of topics and concepts which represent the chosen subject matter area. It is also necessary to ensure that the formal relationships between the concepts are made explicit within the network. The final network within which the student work is called an **entailment structure**" [68] (emphasis in the original). There were two practical barriers to adoption of Pask's framework. Firstly, Pask specified a complex set of structures and organizations for the implementation of conversations [69]. These requirements were not adopted by Laurillard, who adapted some of Pask's ideas in her own conversational framework [70]. Secondly, the development of entailment structures for any individual topic was hugely time consuming. It is reasonable to propose that LLMs could provide an entailment structure, as there is no doubt that they provide "a network of topics and concepts which represent" any topic that a student might choose. LLMs can also be interrogated regarding formal relationships between concepts, though these not always explicit. Whatever the detail of correspondence with Pask's theories, there is certainly an opportunity for students to use LLMs as an opportunity to explore concepts and the relationships between them, and as an emulated interlocutor with which to test their understanding, in combination with conversations with humans (including written and other media exchanges).

In addition to the benefits proposed for GenAI in education, several problems have been identified. Daniel Dennett has recently expressed concerns about GenAI creating 'counterfeit humans' and proposed that this should be outlawed [71]. This argument is consistent with our discussion in this paper and would serve to clarify human-machine communication. In a similar vein, the European Writers Council [72] has condemned many aspects of GenAI, including that "Uncontrolled AI output is being pushed into the bestseller lists with click farms",

often with "identity theft and name deception". There is clearly a danger that such materials will mislead and confuse students. Other studies have reported that the underlying AI models may be biased leading to inaccurate decisions or results [73] and reinforce stereotypes [74]. Guleria and Sood [75] identify a lack of transparency and the explainability of the output of GenAI, contrasting 'black box' machine learning systems with 'white box' systems based on "inductive logic programming, rule learners, etc."

These concerns all revolve around the reliability and transparency of GenAI. Greater transparency of training data and Dennett's proposed prohibition of counterfeit humans would help in this, but it remains impossible to know exactly how and why deep neural networks produce a particular output. It seems more feasible to use these systems to manage uncertainty rather than in an attempt eliminate it, and to treat their output as explorations or predictions with varying degrees of accuracy and relevance. These can feed into human discussion and analysis, a role for which teachers are well suited.

Given an appropriate understanding of human-machine communication, generative AI has much to offer to education institutions. Pask's conversation theory provides a starting point for an exploration of the educational potential of GenAI which is compatible with the coordination paradigm of communication and has a clear role for teachers.

X. Conclusions

This paper has discussed four related domains and argues that each of them can be seen as being informed by a transmission paradigm or by a coordination paradigm. This is summarized in Table IV.

TABLE IV. Domains and Paradigms

Domain	Transmission paradigm	Coordination paradigm
Nature of communication	Conduit of information (misapplication of Shannon and McCulloch)	Coordination (Maturana and Varela's autopoietic theory)
Models of learning	Delivery model of learning, knowledge and understanding	Constructivist view of learning, knowledge and understanding
Implication for understanding of GenAI in teaching and learning	AI passes exams, so it must have human-like intelligence. But we know that it does not. Result: paradox and rejection	AI disrupts teacher-student interactions but creates many opportunities for learning. Result: challenge and adaptation
Expected institutional response to GenAI	Applications of Gen AI focused on selected existing functions, and retrenchment of traditional educational organization.	Broad application of Gen AI, and rethinking of educational organization and instruments

We have argued that the two paradigms are strongly interconnected vertically in Table IV: i.e. the model of the nature of communication that is adopted determines the model of learning, which in turn molds the response of teachers and institutions to GenAI. Because of the vertical interconnection of the paradigms, contradictions will be generated if an institution seeks to make use of the benefits of GenAI in its teaching and learning, while maintaining its existing use of organization and instruments based on the conduit paradigm. It may be expected that this will then disturb the *modus vivendi* between the organizational structures and instruments of the institution and the practice of teachers and create tensions within the institution. This

implies that institutions should recognize that the educational use of GenAI has greater systemic implications for pedagogy than earlier generations of learning technology, and implications for educational organization and instruments which are greater than any seen since the emergence of the internet.

Educational institutions will have to decide to what extent they will persist with the present model of education in the face of a far greater degree of tension between the transmission paradigm and the realities of teaching and learning, or if they will undertake a serious re-examination of educational processes in the light of developments in AI. Similarly, educational researchers will have methodological challenges in understanding and measuring educational processes based on coordination rather than transmission. Researchers, teachers, and educational administrators will need to take a position on these questions, if they are to avoid confusion in their practice, research, and findings.

As authors of the present study, we are fully aware that we have not provided a complete survey of the fields of information, communication, and pedagogy. Nor would this be possible within the confines of a journal paper. Rather, our purpose has been to distinguish and characterize two paradigms which we believe clarify the questions raised by GenAI for institutions, and to explore their implications. We believe that the distinctions which we have made can help institutions, educational leaders, and teachers to frame the complex and nuanced questions raised by GenAI, and to chart a course towards its effective use in education.

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