# Editorial
# Interdisciplinary Artificial Intelligence Research With Machine Education as an Example

## I. Introduction

In THIS editorial, I pose the question of how we can increase the number of papers we publish on interdisciplinary artificial intelligence (AI) in the IEEE Transactions on AI (IEEE TAI). Some of our readers may disagree with the premise of the question. After all, IEEE TAI has published many application papers with multidisciplinary teams, and IEEE TAI hosted a theme on COVID-19 that saw papers bringing together medical practitioners and computer, data and AI scientists, information systems researchers, software engineers, and more. In addition, IEEE TAI has published papers on AI in healthcare, agriculture, drug discovery, cyber security, physics, and more, involving collaborations among diverse team members. However, I label these papers "multidisciplinary" and not "interdisciplinary."

Multidisciplinary research brings scientists from diverse fields to achieve something none can achieve in isolation. Multidisciplinary research is a force multiplier; it creates nonlinear momentum at the intersection of different fields. Interdisciplinary research typically emerges from this momentum but then undergoes a diffusion process that leads to a new form of science with its own identity, principles, and theories.

Consider "bioinformatics" as an example (see item [A1] in the Appendix for a proper history of the field)—a field that commenced with the application of computer science to biology, similar to the multidisciplinary papers IEEE TAI has been publishing but evolved until it became recognized in a scientific journal with the first volume of the Bioinformatics Journal published by Oxford Academic in 1985 and is now a recognized field with its own experts, culture, and challenges.

Can this happen for AI? How will the AI field be transformed into spin-offs with new forms, cultures, and scientific principles? What form of collaborations would lead the AI field to new cutting-edge interdisciplinary areas? What is the future hiding for new interdisciplinary areas of intelligence?

While I have a lot to say regarding these questions, the most crucial question for this editorial is how IEEE TAI can publish the foundational work in these new fields. I believe IEEE TAI should lead the way in this space; after all, the journal's scope covers all aspects of AI, from software to hardware, from theory to applications, and, as I assert here, from well-established ideas to revolutionary ones. To answer this last question on how foundational work in emerging interdisciplinary AI can appear in IEEE TAI, I draw on the example of "machine education," taken from my own work; I aim not to promote the idea but to illustrate the opportunities and challenges.

## II. Machine Education—An Interdisciplinary AI Example

On a very technical, computer science level, machine education is concerned with the specifications of the curriculum (including data) to be presented to a machine learner, and the test and evaluation, assurance, and accreditation of this curriculum to certify that the AI-enabled technology is socially ready (functional, safe, ethical, legal, compliant, responsible, to list but a few necessary properties).

From a futurology perspective, machine education suggests the premise that we need to take AI-enabled machines to schools and universities, like humans go to these institutions, to acquire knowledge and shape their minds to become professionals. Responsible citizens learn about professionalism, including ethics, the social impact of their knowledge, and legal issues. My IEEE Day's presentation (https://www.youtube.com/watch?v=gCUTEd-6Szw) discusses the scientific evolution that is making machine education an imminent reality.

Today, we witness plentiful discussions and papers on ethics and AI, regulatory frameworks and AI, social integration of AI, trusted AI, certification of AI, test and evaluation of AI, responsible AI, accountable AI, and fairness in AI—and some are even talking about honest AI. Others with whom I have a personal acquaintance are exhausted by these discussions as they offer principles with little to no "real" steps toward operationalization. How to transition from "talk" to "execution" and "operation"? Computer scientists have answered this question since almost the inception of the computer science field, and the answer is one word: mathematics. Through mathematics, the ambiguity and imprecision of human language are replaced with concise statements that form unambiguous specifications for an implementable system that can be verified, validated, tested, evaluated, assured, certified, accredited, approved for use, and precisely explained to others. However, before reaching rapid and inaccurate conclusions, mathematics alone is insufficient.

While computer science offers the mathematical constructs to make this possible, ambitious interdisciplinary ideas will not materialize purely by focusing on computer science alone. We incorporate people from diverse fields, including social scientists and humanity researchers. In machine education, experience, including data, is an integral part of the curriculum. At the very

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least, we would demand that the data are vetted by domain experts. However, we also need social scientists to form an integral part of the team to design the data for the curriculum. Experts from diverse disciplines, including ethics, psychology, social engineering, cognitive engineering, education, law, policy, and regulators, should be key members of the data engineering component of the curriculum. The importance of this diversity is twofold: 1) to bring subject matter experts in human and social sciences to the lesson design for an AI, and 2) to mitigate risks *a priori* of the deployment and social integration phase. For example, our core machine education team consists of an education expert, primarily in Teaching English as a Second or Other Language, and an expert in systems thinking and participatory modeling. We have an education-focused Ph.D. candidate and a research fellow who is an engineer with postgraduate studies in AI and a Ph.D. in human–swarm interaction. In addition, I contribute both my AI skills and more than 30 years of experience leading interdisciplinary teams.

In our work on machine education, we aim not to "just" talk about ethics for AI or accountability in AI; we aim to operationalize these concepts. Any initial instantiation of this sort will likely be unsatisfactory, lacking universal acceptability. Properties, such as universal acceptance, take time to guarantee; perhaps we will never guarantee them for some implementations. However, we must take steps to show "real" grounding of the concepts. We need to start with one possible "what" (i.e., specifications) and show one possible "how" (i.e., an implementation and use case). Some implementations will be fit-for-purpose while others will be heavily and constructively criticized. Science evolves naturally from there. In our machine education work, we use shepherding (an AI to herd sheep) as our use case to ground the concepts.

If this area grows, what are the possible paths the journey might take? In IEEE TAI, we could start with multidisciplinary papers. Indeed, IEEE TAI has papers and special issues that have been accepted or are under review on some topics, attempting to cover the ethics, explanation, and operationalization of responsible AI. We are taking the first steps. But let me now share the pain and the actual operational challenges in bringing interdisciplinary publications to light.

## III. Reviewing Interdisciplinary AI in IEEE TAI

Imagine I submit a paper on machine education to IEEE TAI. Note, importantly, that I would not send any paper of mine to IEEE TAI while I am the Editor-in-Chief (EiC), to avoid a conflict of interest, but, for the sake of argument, let me put myself in the shoes of such authors. What are the hurdles to publishing this work?

First, only a few scientists internationally would possess the combined skills to assess the paper technically. Most researchers at the intersection of AI and education use AI as a technology to support education or educate humans about AI; less than a handful is working on the pedagogy for educating an AI, and this handful are usually too busy to accept papers to review. We could split the effort. For example, one reviewer could cover machine learning, and another cover, say, the ethics or education component of the paper. However, these specialists are not used to the intersection or interface of science; they did not grow to maturity in this interface, and their brain needs to be shaped to process the information that sits deep within this interface.

Imagine the early days of a bioinformatics paper going to a classic biologist or computer scientist; they would see the paper as speculative or an application lacking an in-depth contribution to their specific field. They would most likely, as evident through history, reject the claims in the paper and, subsequently, the article itself. While those who research the process and conduct of interdisciplinary research know the theory, they would need to be an expert to judge an interdisciplinary topic; for example, a researcher who works on designing interdisciplinary research would need significantly more knowledge to judge, say, a bioinformatics paper.

How to find the right reviewers? How to convince them to spare the time to assist the journal? How to find specialists with minds open to interdisciplinary science? These are all practical challenges on the ground when operating a journal. Second, how to avoid a wave of naïve paper submissions claiming to be interdisciplinary without having the depth in their theses to advance science?

The interdisciplinary papers I am discussing here are not the classic experimental or theoretical science type; I am referring to papers published by early pioneers, not the axiomatic and mathematical, but the visionary and architectural (see for example items [A2], [A3], and [A4] in the Appendix). Some companies try to present these as white papers. However, similar to most journals, we do not have a white paper category in IEEE TAI, and it would be hard to justify; perhaps we should formalize the quality measures of a category of this sort.

I do not particularly appreciate posing challenges without possible solutions. We need special issues in the journal that focus on cutting-edge research, on areas where the guest editors are world leaders and the areas themselves deserve recognition in a special issue. We also need a multidisciplinary and interdisciplinary pool of reviewers. I urge every scientist working at the interface of AI with humanity, social sciences, education, and other fields to create cutting-edge interdisciplinary research areas to reach out and join the review pool of the journal. These same scientists find it difficult to publish their work, principally because similar researchers are not available to review papers. We need visionary and skilled people at the interfaces of science to publish high-quality articles in these areas. I invite you to drop me an email with your ideas and reflections.

Last, I urge the community to balance exploiting AI's trend-driven and hyped areas with the looking-ahead mindset needed to innovate scientifically and rigorously. To see what could be lying ahead in the AI field. I invite you all to reflect, look ahead, reflect again, innovate, form ideas—and submit them to IEEE TAI. But also, join the journal as a reviewer and choose your keywords to ensure you are ready for the work you can assess.

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## APPENDIX: RELATED ARTICLES

[A1] J. Gauthier, A. T. Vincent, S. J. Charette, and N. Derome, "A brief history of bioinformatics," *Brief. Bioinf.*, vol. 20, no. 6, pp. 1981–1996, Aug. 2018, doi: 10.1093/bib/bby063.

[A2] J. C. Licklider, "Man-computer symbiosis," *IRE Trans. Human Factors Electron.*, vol. HFE-1, no. 1, pp. 4–11, 1960.

[A3] J. J. Vidal, "Toward direct brain-computer communication," *Annu. Rev. Biophys. Bioeng.*, vol. 2, no. 1, pp. 157–180, 1973.

[A4] J. McCarthy, M. L. Minsky, N. Rochester, and C. E. Shannon, "A proposal for the Dartmouth Summer Research Project on Artificial Intelligence, Aug. 31, 1955," *AI Mag.*, vol. 27, no. 4, pp. 12–14, 2006.