Proceedings of the Human Factors and Ergonomics Society Annual Meeting
1–5

DOI: 10.1177/10711813251376982
journals.sagepub.com/home/pro
Sage

Integrating Generative Artificial Intelligence into Interdisciplinary Research: Cognitive Requirements and Implications for Design

Christen E. Sushereba[1], Laura G. Militello[1], Rachel Morris[1], Sowmya Ramachandran[2], Julie Diiulio[1], and Akul Sarin[2]

Abstract

This paper describes a cognitive task analysis (CTA) for developing design recommendations to inform the design of a tool that supports interdisciplinary research using generative artificial intelligence (GenAI). The Generative Embeddings Network-based Semantic Inference and Search (GENESIS) prototype is being developed to enable researchers to explore and understand fields of knowledge beyond their areas of specialization. CTA findings include a task diagram outlining three main tasks of interdisciplinary research (information seeking, integration, and creation), cognitive requirements associated with each task, and design recommendations for integrating GenAI into the interdisciplinary research process.

Keywords

cognitive task analysis, generative AI, interdisciplinary research, task diagram, cognitive requirements

Introduction

In this paper, we describe the results of cognitive task analysis (CTA; Crandall et al., 2006) that was conducted to support the development of a prototype tool designed to support interdisciplinary research and collaboration.

Generative Artificial Intelligence (GenAI) tools are increasingly being used to support research and learning. However, there are challenges that limit the usefulness of tools currently available, particularly in the pursuit of scholarly research. Although chat-based GenAI tools appear simple to use, understanding how to leverage them effectively can be a challenge. For example, prompt engineering is a skill that many people develop to help them frame prompts to produce the exact desired outputs. Additionally, the prevalence of realistic "AI hallucinations" and inaccurate information requires additional skill in recognizing the potential for errors, along with the inaccuracies themselves (for a recent example of AI hallucinations from the news, see Weber & Gilbert, 2025).

In the current project, we employed CTA methods for articulating key tasks and cognitive requirements to inform the design of a tool that supports interdisciplinary scholarly research using GenAI. The Generative Embeddings Network-based Semantic Inference and Search (GENESIS) prototype is being developed to empower researchers to explore and understand fields of knowledge beyond their areas of specialization.

Background

Effective interdisciplinary research relies on the integration of diverse sources of information. The integration of multiple perspectives and disciplines via interdisciplinary learning has been shown to enhance critical thinking, deepen learners' understanding of complex concepts, and support learners in drawing connections between disciplines and developing more nuanced understanding of subjects and domains (Lupo et al., 2019; Tan et al., 2021). Applying one's own expertise in a new domain often requires an understanding of the new domain. For example, we interviewed one scientific applications engineer working at a super computing site who described the lengthy process it took to apply his expertise related to code optimization to support a research team. He

[1]Applied Decision Science, Dayton, OH, USA
[2]Stottler Henke Associates, Inc., San Mateo, CA, USA

Corresponding Author:
Christen E. Sushereba, Applied Decision Science, 5335 Far Hills Ave, Dayton, OH 45429, USA.
Email: c.sushereba@applieddecisionscience.com

needed to verify that the code produced accurate results, but he lacked the domain knowledge to make such judgments himself. The interviewee reported that the process of learning how to interpret and understand the output took months of collaboration with the researchers.

Today, such cognitive complexities associated with interdisciplinary collaboration are primarily supported by independent learning, close collaboration with experts, and apprenticeship. AI tools may play an important role in navigating these complex, real-world challenges.

Generative AI and Large Language Models

GenAI and large language models (LLMs) are potentially powerful tools that are being used to support interdisciplinary learning and research in several ways. First, the influence of conversational AI, such as ChatGPT and Google Gemini, are being increasingly recognized for their ability to tailor educational experiences to individual needs, fostering interdisciplinary knowledge acquisition (Chen & Huang, 2012; Hui et al., 2022; Ma et al., 2023; Rahayu et al., 2023). Second, research findings suggest that integrating AI into interdisciplinary learning to personalize learning pathways has the potential to support the development of cognitive flexibility and problem-solving skills, enabling researchers to effectively bridge disciplinary boundaries (Chen et al., 2020; Jia et al., 2021). Third, some literature suggests that AI's ability to process and analyze vast amounts of data can lead to more efficient and innovative solutions (Baum, 2021). Moreover, systems that leverage global topic models, user models, and expertise models have been found to expedite the development of expertise by assessing users' knowledge levels, setting targeted goals, and recommending tailored learning activities (Fergusson, 2022; Peng et al., 2022; Smith et al., 2003).

GENESIS Prototype

GENESIS is a platform designed to empower researchers to explore and understand fields of knowledge beyond their areas of specialization. It features a chat-based user interface, which allows scientists to ask questions and receive synthesized responses tailored to their preferences. GENESIS responses are grounded in real and pertinent information, providing knowledge from diverse scientific fields as well as offering accurate citations.

GENESIS utilizes a structured knowledge graph to organize and connect scientific information. This knowledge graph serves as the foundational component for GENESIS's advanced reasoning, retrieval, and personalization capabilities. Its primary purpose is to act as a comprehensive and dynamic repository of information. Key design goals for the knowledge graph included comprehensive coverage of scientific domains, interconnectedness to facilitate multi-hop reasoning, dynamic updates to maintain currency, scalability to handle the growing volume of research, and adaptability to new domains and information types. The knowledge graph is deeply integrated within GENESIS, powering its retrieval capabilities through a modified HippoRAG (Jimenez Gutierrez et al., 2024) architecture, enabling complex reasoning tasks, and providing transparent explanations for its outputs. The HippoRAG framework, inspired by the hippocampal indexing theory of human memory, offers a novel approach to knowledge integration within retrieval-augmented generation (RAG) for LLMs. This approach involves constructing a schema-less knowledge graph from a corpus of text using an instruction-tuned LLM. This mimics the neocortex's role in human memory. The knowledge graph serves as an artificial hippocampal index, storing salient information extracted from the text, and thereby grounding the information provided by GENESIS.

The HippoRAG architecture enables a multi-stage hybrid search technique that combines the power of LLMs with advanced logical reasoning capabilities to ensure the logical soundness and relevance of responses. Knowledge graph search and semantic reranking makes results more reliable for scientific research and knowledge integration, overcoming a common limitation of LLMs in which results are inaccurate or completely fabricated (i.e., hallucinations). GENESIS also utilizes state-of-the-art pre-trained encoder/embeddings models that are optimized for reasoning-based retrieval across a vast corpus of scientific publications. GENESIS can retrieve images, figures, equations, and tabular data along with textual information, providing a rich and multimodal knowledge base from which to generate responses to user queries.

GENESIS uses novel prompt-engineering techniques to tailor responses to individual scientists' preferences and research interests, ensuring users receive customized and relevant information, optimizing their knowledge discovery process. Future versions of GENESIS will implement a Reinforcement Learning from Human Feedback loop, allowing the GENESIS system to continuously learn and improve its own performance. Through this feedback loop, GENESIS delves deeper into domain-specific semantics within scientific disciplines, leading to increasingly relevant search results and more effective knowledge integration.

Method

We conducted a CTA, analyzing interviews with four personnel from the Ohio Supercomputer Center (OSC) who help researchers conduct interdisciplinary research. Interviews included three activities: (1) discussion of participant role, (2) exploration of participant's use of GenAI tools, and (3) participant response to a hypothetical interdisciplinary research scenario in which they are asked to imagine using GenAI. Also included in the CTA were data from interviews with 21 potential users of GENESIS; these interviews focused on understanding how interdisciplinary research is

carried out and the types of support that a GenAI tool could provide to improve the process. Interview notes were qualitatively analyzed to identify tasks for conducting interdisciplinary research, experiences using GenAI and other related technology, strategies used to conduct interdisciplinary research, and associated challenges. From this analysis, we articulated a task diagram (Militello & Hutton, 1998), cognitive requirements that capture the challenging cognitive work, and design recommendations for GENESIS.

Outcomes

Most interviewees described research processes they used with no or limited use of GenAI. The resulting task diagram reflects their experiences and the strategies and tools they use today. The cognitive requirements emphasize forward-looking requirements that are relevant for GenAI tools to better support the process and inform design recommendations for GENESIS. The tasks and cognitive requirements are shown in Figure 1 and discussed next.

Task Diagram

We identified three main tasks of conducting interdisciplinary research: information seeking, integrating disparate information sources, and creating a knowledge product.

The first step in the task diagram, information seeking, begins with determining goals of the research effort. During this step, information is identified and accessed, usually using a search engine via the use of targeted search queries. The researcher must determine the relevance of search results, manage information, and review content. For larger efforts, these activities may also need to be coordinated across a team of researchers.

The second step, integration, involves critically evaluating the resources found during the first step and integrating the information to answer the original goals of the research. The complexity of this task depends on the breadth and depth of the overall research effort. For interdisciplinary research, the integration task often involves abstracting one's own domain knowledge to understand concepts and ideas in the new domain.

The third step, creating, refers to the product that is generated from the research effort. Products range from relatively informal notes or emails; written scholarly products such as reports, proposals, and articles; presentations and briefings to stakeholders; and classroom/training materials designed for broader dissemination.

Cognitive Requirements

We identified eight cognitive requirements across the three steps identified in the Task Diagram. The cognitive requirements associated with the first step in the task diagram, information seeking, include:

1. Scope the research effort - Scoping a research effort requires defining goals, specific questions, objectives, etc., that can be achieved given the relevant constraints (e.g., timeline, available resources, etc.).
2. Find the right information - Search engines and databases generate many results, which must be organized and evaluated (e.g., separating the "wheat from the chaff").
3. Manage information - Once information has been collected, the researcher must manage information overload and be able to review the gathered information, sometimes coordinating with a team.

Strategies for this phase of interdisciplinary research include speaking with domain experts to identify thought leaders and key concepts. Additional strategies include starting with high-level topic overviews to guide further searches, using GenAI to clarify concepts, and using reference managers to track of key literature.

Cognitive requirements associated with the second step of the task diagram, integration, include:

4. Integrate and synthesize information—Researchers must be able to understand the information well enough to determine whether they are achieving the goals of the effort.
5. Answer research questions—Researchers must understand information to answer original research goals to create some artifact (report, presentation, article, proposal, etc.).

Strategies employed to support the integration phase include using analogies to connect new concepts to one's own domain of expertise and seeking feedback from experts in the target domain.

Cognitive requirements for the last phase of the task diagram, creating, include:

6. Structure and draft content—Content must be structured and drafted according to the ultimate goals of the research product. When using GenAI, this step requires using very specific prompts.
7. Cite sources—Research products need to be able to cite references that support what is being said. Many GenAI tools do not reliably produce accurate citations.
8. Edit and revise—Researchers must review content and revise. When using GenAI, an added editing task to identify and correct AI hallucinations is required.

When using GenAI to create content, strategies that were reported included using prompts to produce output and allocating time to review GenAI-created content for hallucinations, incorrect references, and double-checking citations.

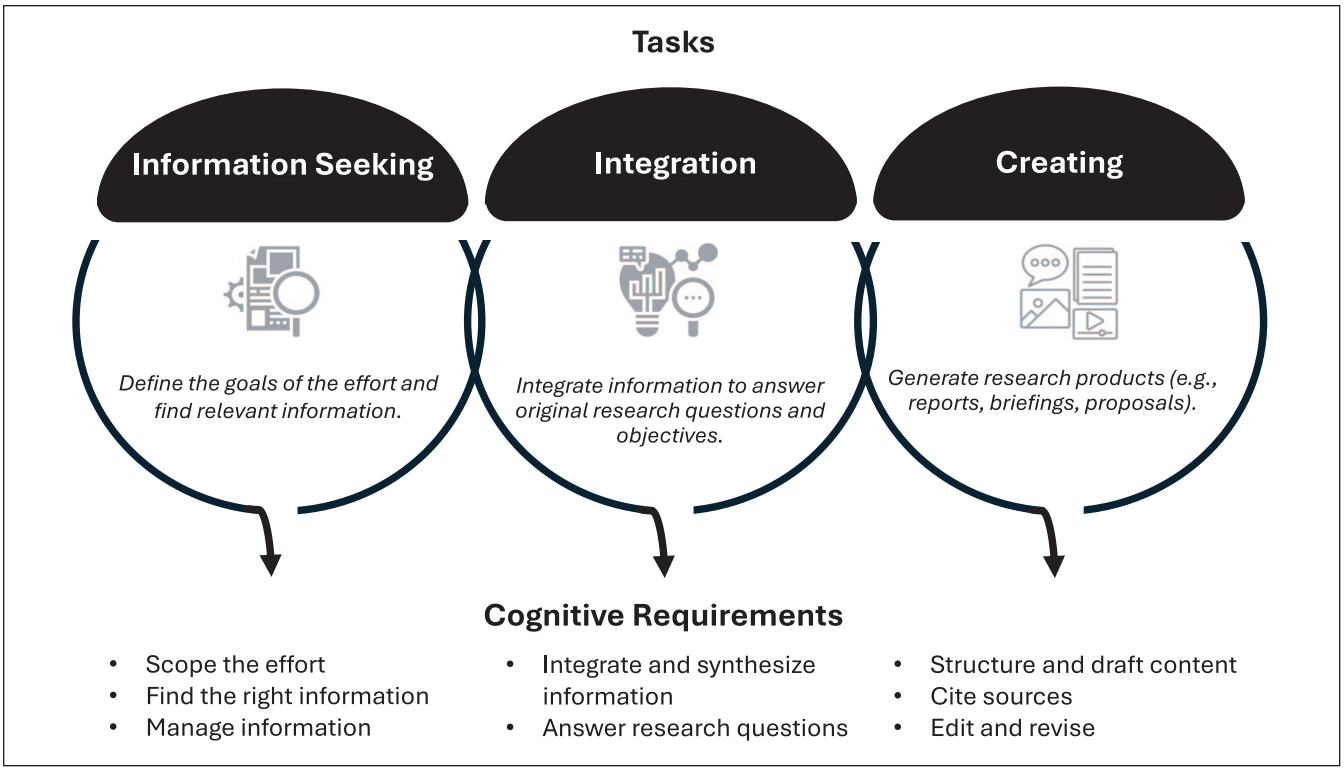

Figure 1. Task diagram and cognitive requirements.

GenAI Design Recommendations

From these cognitive requirements, we generated a set of design recommendations for the GENESIS prototype tool to more effectively integrate GenAI into the interdisciplinary research process.

To support the cognitive requirements of the information seeking phase, we recommend the following design features: (1) intelligent AI prompt suggestions based on user-defined goals, (2) accurate integration of information from disparate sources with clear distinctions between facts and perspectives/opinions, (3) user control over the research direction and customization based on specific goals or interests, and (4) alerts when a topic has been comprehensively covered. Finally, AI should incorporate critical appraisal mechanisms to ensure reliability, relevance, and applicability of generated content and insights, along with reliable citations and evaluations of sources to highlight information that may not be reliable.

In support of the cognitive requirements associated with the integration tasks, design recommendations include AI features to help users interpret search results in terms of research goals. These include providing concise summaries that integrate content from several sources, translating complex information into easily understandable textual descriptions, and summarizing research findings to make complex data more accessible and comprehensible for interdisciplinary audiences.

Design recommendations were also articulated to support users in content creation tasks. A GenAI tool should use techniques that reduce hallucinations and base the information produced in trusted and reliable sources. Additionally, applications can support integrated notetaking and insight tracking, along with critical evaluation mechanisms to check (human and GenAI) composed content for reliability and accuracy.

Conclusion

Some of the individuals interviewed reported currently using GenAI tools in the information seeking and content generation tasks, but not the integration task. Design recommendations include strategies for ways that GENESIS could integrate GenAI during all three tasks of interdisciplinary research.

GENESIS is being designed to address both the technical limitations and user interaction challenges of using GenAI to effectively support interdisciplinary research. The multi-stage hybrid search technique employed by GENESIS provides advanced logical reasoning capabilities to generate accurate responses. This, combined with a user interface informed by cognitive requirements, will support users in leveraging GenAI to produce desired scholarly outcomes.

GENESIS is envisioned as a tool that uses LLMs and GenAI to bridge disciplinary gaps, enabling users to

understand complex domains outside of their own expertise. The work presented here focuses on the required interface elements to allow GENESIS to fully support scientists engaging in interdisciplinary research, highlighting the types of support that humans need to make a partnership with GenAI more effective for users while shortening the learning curve associated with using GenAI. The goal of GENESIS is to leverage the strengths of both GenAI and human expertise in conducting interdisciplinary research.

Authors' Note

The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

Declaration of Conflicting Interests

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

The authors disclosed receipt of the following financial support for the research, authorship, and/or publication of this article: This material is based upon work supported by the U.S. Department of Energy, Office of Science, Office of Advanced Scientific Computing Research, under Award Number DE-SC0024860. This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof.

ORCID iDs

Christen E. Sushereba https://orcid.org/0000-0001-7523-9671
Laura G. Militello https://orcid.org/0000-0001-8445-5640
Sowmya Ramachandran https://orcid.org/0000-0001-7323-958X

References

Baum, S. D. (2021). Artificial interdisciplinarity: Artificial intelligence for research on complex societal problems. *Philosophy & Technology*, *34*, 45–63. https://doi.org/10.1007/s13347-020-00416-5

Chen, H-R, & Huang, J-G. (2012). Exploring learner attitudes toward web-based recommendation learning service system for interdisciplinary applications. *Journal of Educational Technology & Society*, *15*(2), 89–100. http://www.jstor.org/stable/jeductechsoci.15.2.89

Chen, Y., Daamen, T. A., Heurkens, E. W. T. M., & Verheul, W. J. (2020). Interdisciplinary and experiential learning in urban development management education. *International Journal of Technology and Design Education*, *30*, 919–936. https://doi.org/10.1007/s10798-019-09541-5

Crandall, B., Klein, G.A., & Hoffman, R.R. (2006). *Working Minds: A practitioner's guide to cognitive task analysis*. MIT Press.

Fergusson, L. (2022). Learning by. . . knowledge and skills acquisition through work-based learning and research. *Journal of Work-Applied Management*, *14*(2), 184–199. https://doi.org/10.1108/JWAM-12-2021-0065

Hui, B., Zhang, L., Zhou, X., Wen, X., & Nian, Y. (2022). Personalized recommendation system based on knowledge embedding and historical behavior. *Applied Intelligence*, *52*, 954–966. https://doi.org/10.1007/s10489-021-02363-w

Jia, Y., Zhou, B., & Zheng, X. (2021). A curriculum integrating STEAM and maker education promotes pupils' learning motivation, self-efficacy, and interdisciplinary knowledge acquisition. *Frontiers in Psychology*, *12*, 725525. https://doi.org/10.3389/fpsyg.2021.725525

Jimenez Gutierrez, B., Shu, Y., Gu, Y., Yasunaga, M., & Su, Y. (2024). HippoRAG: Neurobiologically inspired long-term memory for large language models. *Advances in Neural Information Processing Systems*, *37*, 59532–59569.

Lupo, S. M., Berry, A., Thacker, E., Sawyer, A., & Merritt, J. (2019). Rethinking text sets to support knowledge building and interdisciplinary learning. *The Reading Teacher*, *73*(4), 513–524. https://doi.org/10.1002/trtr.1869

Ma, Y., Ouyang, R., Long, X., Gao, Z., Lai, T., & Fan, C. (2023). DORIS: Personalized course recommendation system based on deep learning. *PloS One*, *18*(6), e0284687. https://doi.org/10.1371/journal.pone.0284687

Militello, L. G., & Hutton, R. J. B. (1998). Applied Cognitive Task Analysis (ACTA): A practitioner's toolkit for understanding cognitive task demands. *Ergonomics Special Issue: Task Analysis*, *41*(11), 1618–1641

Peng, J., Xu, D., Lee, R., Xu, S., Zhou, Y., & Wang, K. (2022). Expediting knowledge acquisition by a web framework for Knowledge Graph Exploration and Visualization (KGEV): Case studies on COVID-19 and human phenotype ontology. *BMC Medical Informatics and Decision Making*, *22*, 147. https://doi.org/10.1186/s12911-022-01848-z

Rahayu, N. W., Ferdiana, R., & Kusumawardani, S. S. (2023). A systematic review of learning path recommender systems. *Education and Information Technologies*, *28*, 7437–7460. https://doi.org/10.1007/s10639-022-11460-3

Smith, A., Goodwin, D., Mort, M., & Pope, C. (2003). Expertise in practice: An ethnographic study exploring acquisition and use of knowledge in anesthesia. *British Journal of Anesthesia*, *91*(3), 319–328. https://doi.org/10.1093/bja/aeg180

Tan, S. C., Chan, C., Bielaczyc, K., Ma, L., Scardamalia, M., & Bereiter, C. (2021). Knowledge building: Aligning education with needs for knowledge creation in the digital age. *Educational Technology Research and Development*, *69*(4), 2243–2266. https://doi.org/10.1007/s11423-020-09914-x

Weber, L., & Gilbert, C. (2025, May 29). White House MAHA report may have garbled science by using AI, experts say. *The Washington Post*. https://www.washingtonpost.com/health/2025/05/29/maha-rfk-jr-ai-garble/