

ICTE 2025

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# Human-AI Collaboration in the STEM Classroom:

A Systematic Literature Review of GenAI as a Complement in Higher Education

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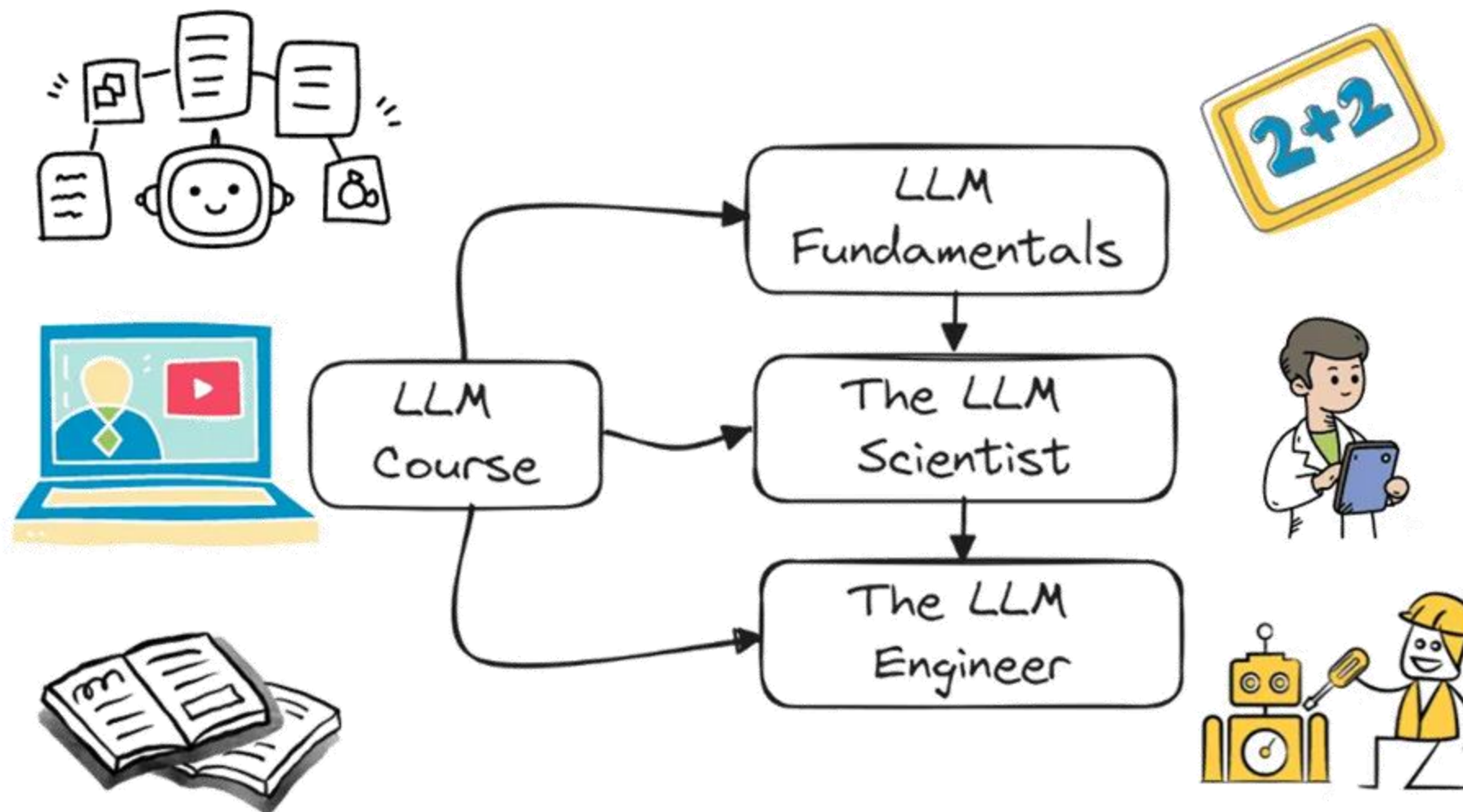
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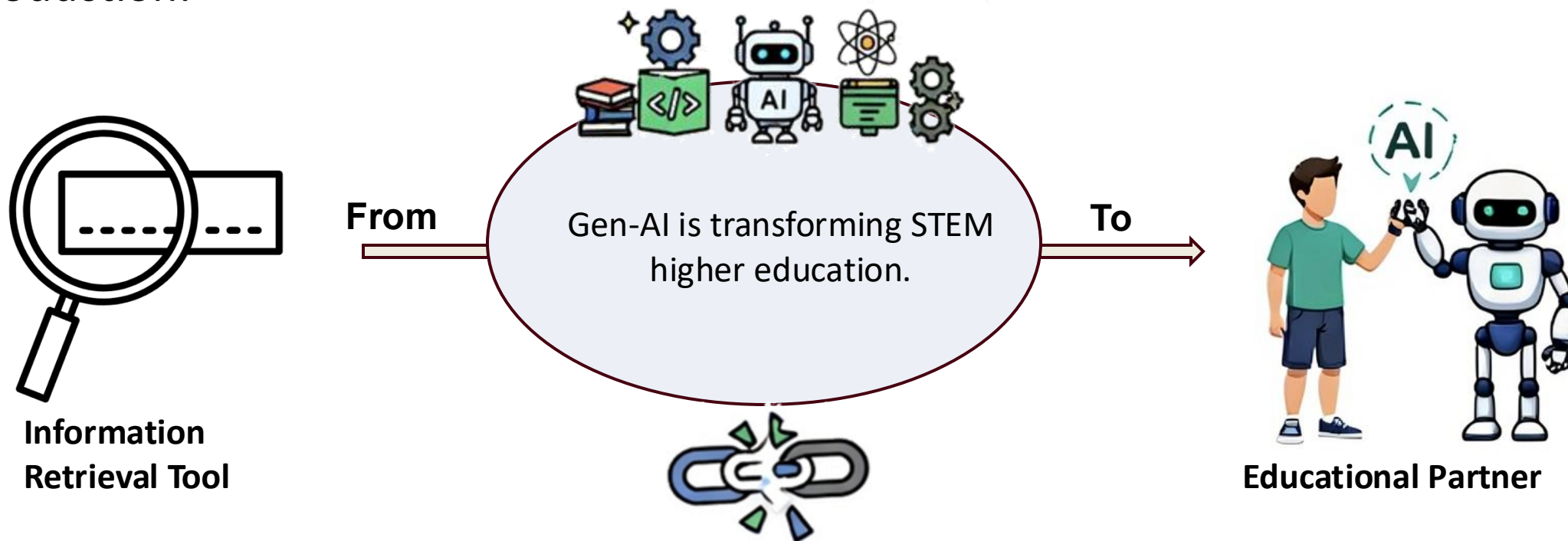
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## I. Introduction:



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**GAP:** Despite widespread applications, there is a lack of systematic reviews on human-machine collaboration models, role changes, and challenges in STEM fields



## I. Introduction:

# Objective

To map the landscape of Human-LLM collaboration based on empirical studies from the last two years.

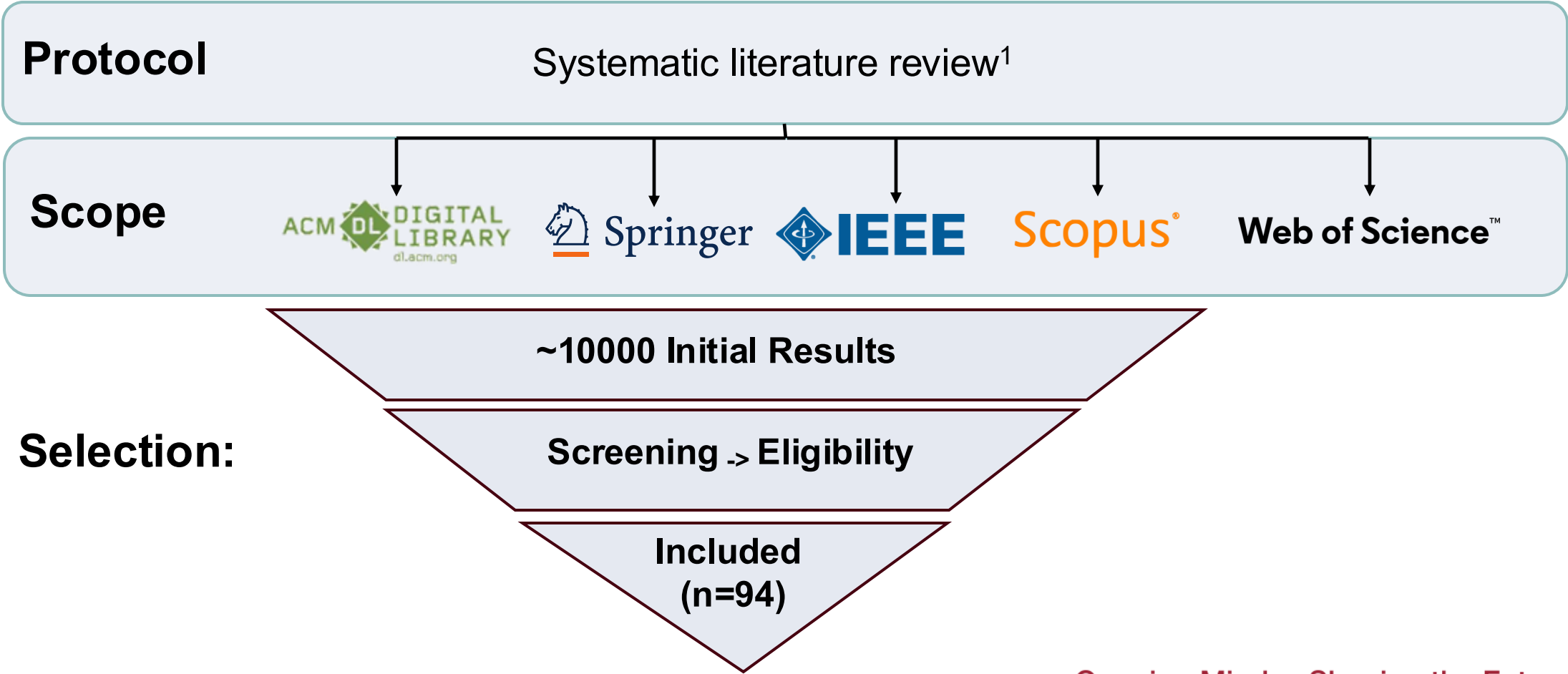


## II. Research Questions:

- **RQ1:** What models of Human-LLM collaboration are described in the literature for STEM education?
- **RQ2:** What are the documented domains of impact of Human-LLM collaboration on student learning outcomes in STEM?
- **RQ3:** How does the adoption of LLMs as collaborative partners affect the traditional roles of students and educators in the STEM subjects?
- **RQ4:** What are the primary challenges and limitations identified in the literature regarding the use of LLMs in a collaborative capacity in STEM higher education?



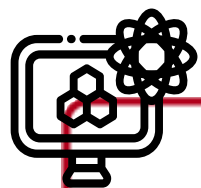
III. Methodology:



<sup>1</sup> Keele, S. & others. (2007). Guidelines for performing systematic literature reviews in software engineering. Technical report, ver. 2.3 ebse technical report.



## IV. Result:



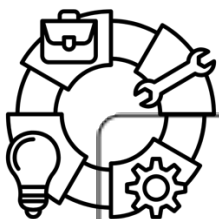
Computer Science  
(n=61)



Biology  
(n=5)



Physics  
(n=4)



Engineering  
(n=13)



Mathematics  
(n=5)



Mixed STEM  
(n=6)

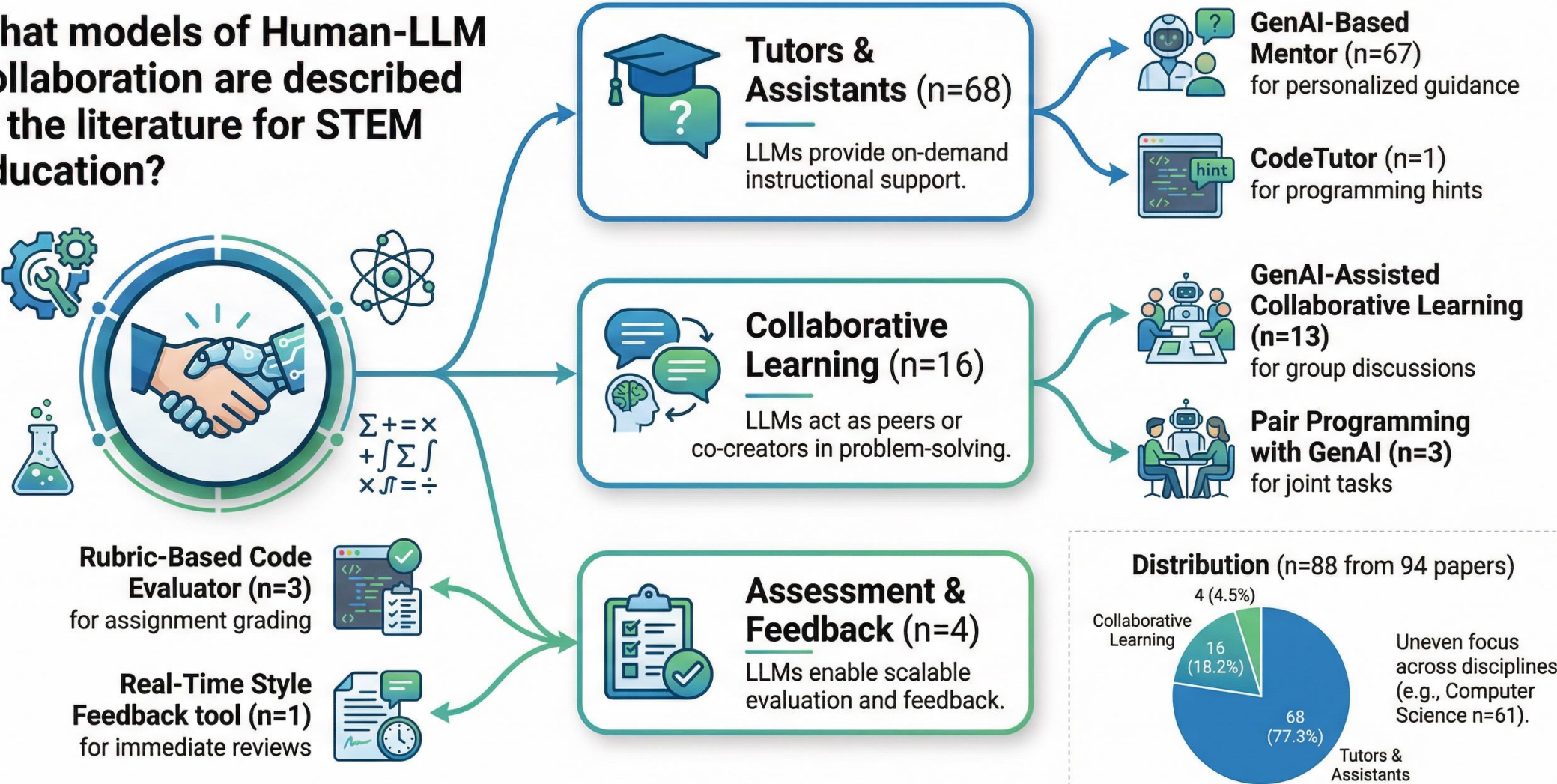




IV. Results

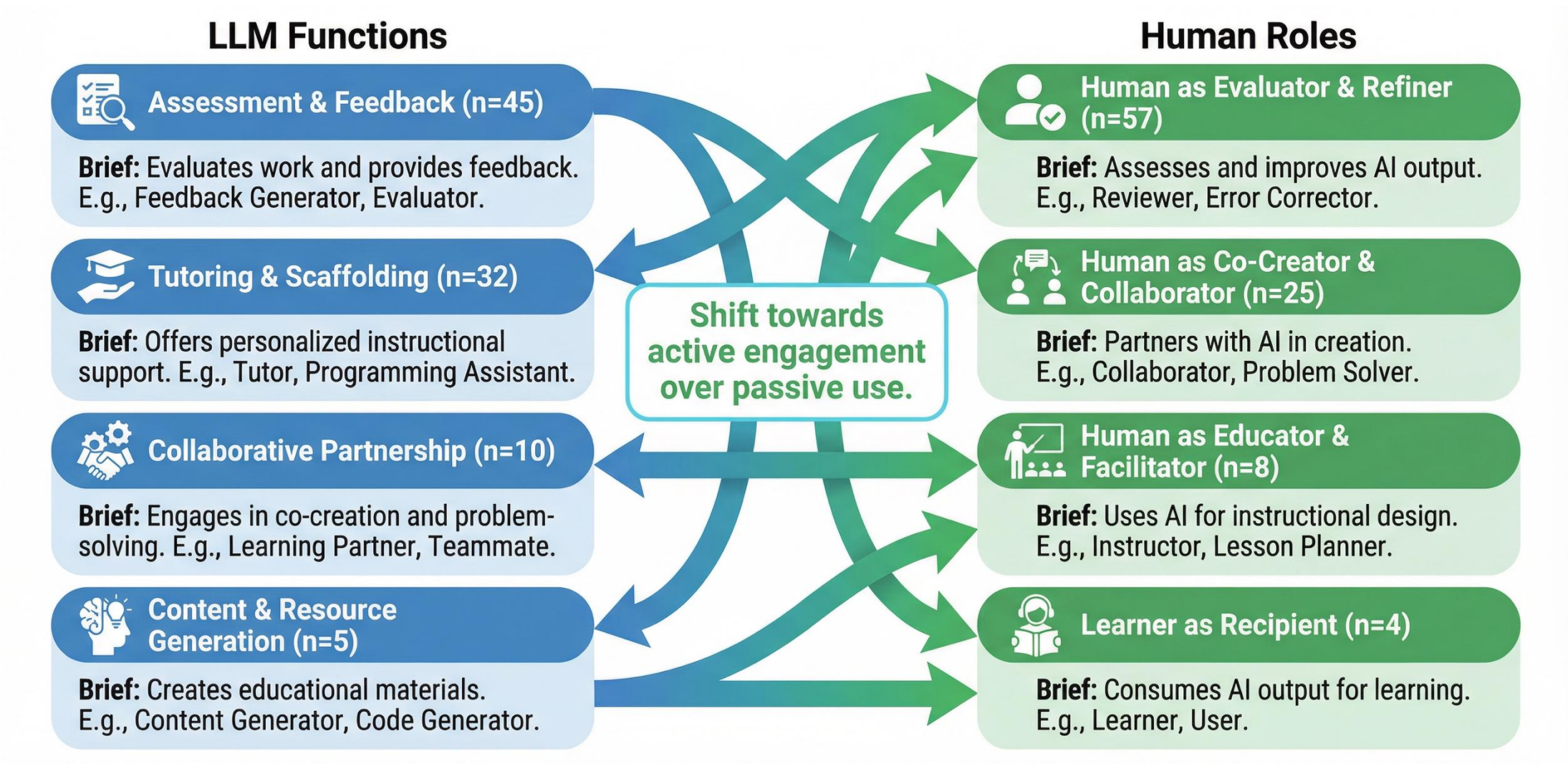
Human-GenAI Collaboration' Models (RQ1)

What models of Human-LLM collaboration are described in the literature for STEM education?





# IV. Results LLM’s Role and Human’s role in Human-GenAI Collaboration (RQ1)

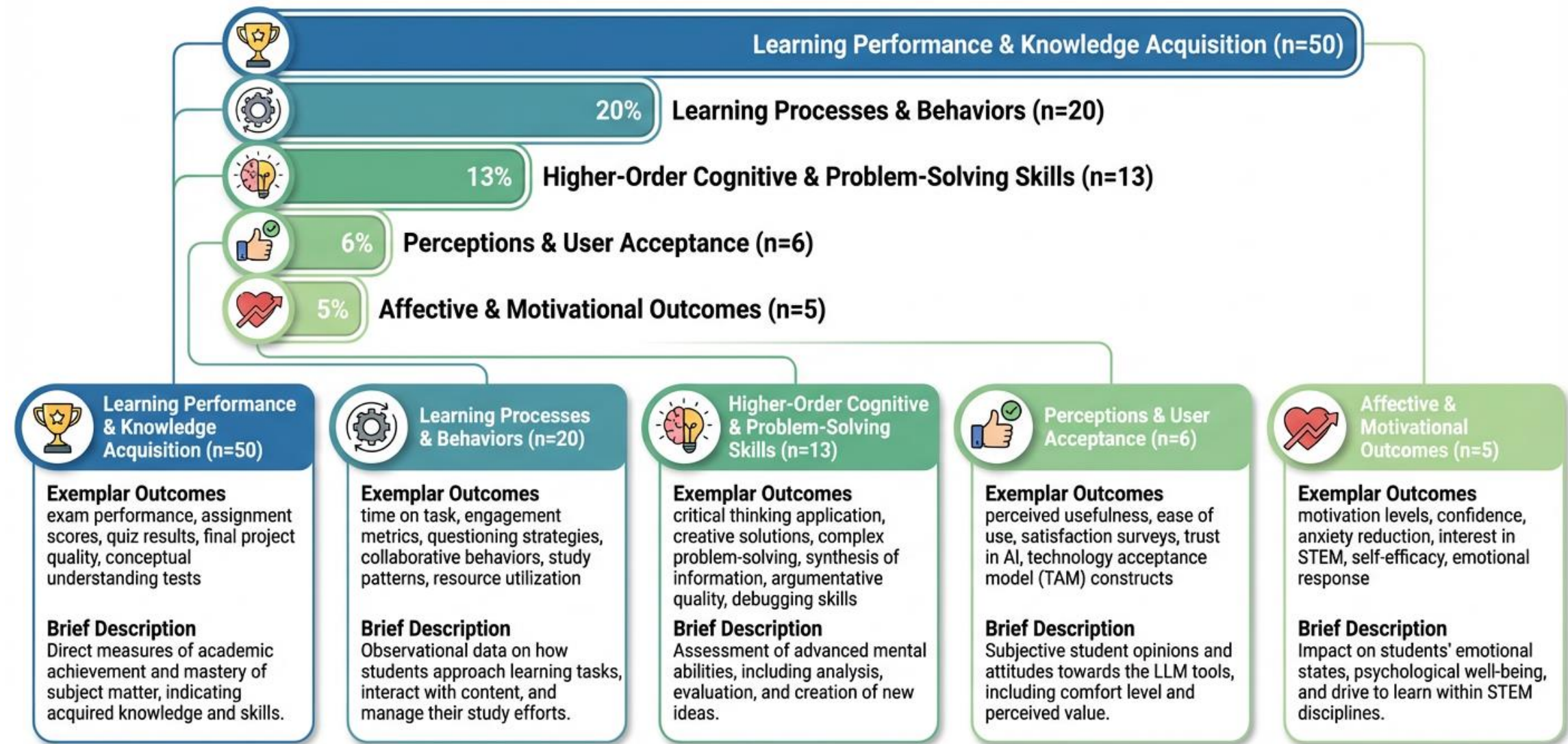






IV. Results

Student learning outcomes in Human-AI Collaboration (RQ2)





# IV. Results

## Student learning outcomes in Human-AI Collaboration (RQ3)



### Student Role Evolution



**AI-Scaffolded Self-Regulator (n=43)**

**Example Changes:**

- Using AI to make independent learning choices;
- Engaging in structured self-reflection facilitated by the LLM

**Brief Description:** The student utilizes AI tools to better manage their own learning processes, including planning, monitoring, and reflection

**Human-AI Co-Creator (n=25)**

**Example Changes:**

- Collaborating with AI to generate code, solve complex problems, and design projects;
- Jointly authoring reports and creative works

**Brief Description:** Students and AI work together as partners to produce outputs, leveraging each other's strengths in a synergistic process

**Active Agent & Critical Evaluator (n=14)**

**Example Changes:**

- Scrutinizing AI outputs for accuracy, bias, and relevance;
- Comparing AI solutions with traditional methods and external sources

**Brief Description:** Students take an active role in questioning and verifying AI-generated information, fostering critical thinking and independent judgment

**Inquiry Director & Prompt Engineer (n=7)**

**Example Changes:**

- Formulating effective prompts to guide AI;
- Experimenting with different phrasings and contexts to optimize AI responses

**Brief Description:** Students learn to direct the AI by crafting precise and strategic queries, becoming skillful at eliciting desired information and results

**Dependence & Altered Pathways (n=4)**

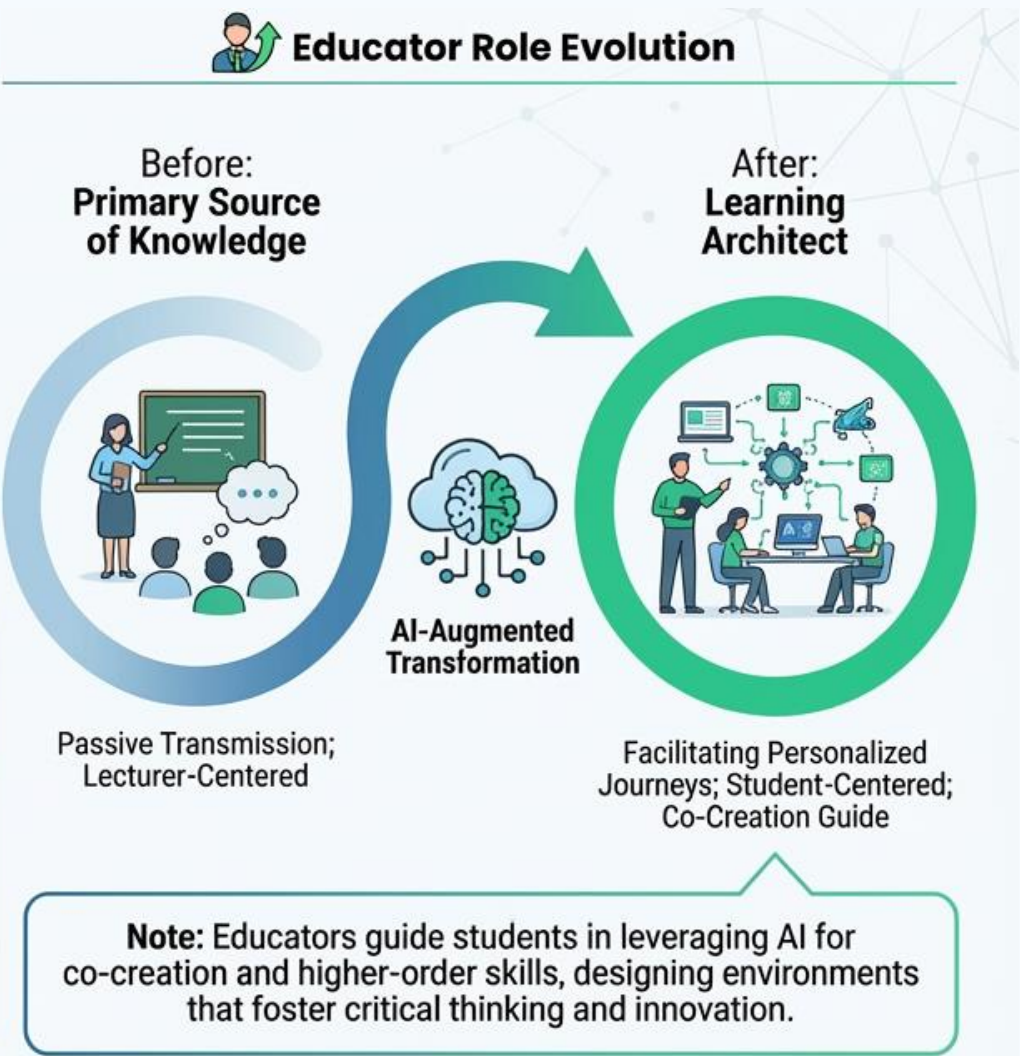
**Example Changes:**

- Relying excessively on AI for problem-solving;
- Experiencing reduced engagement with fundamental concepts or foundational skills

**Brief Description:** Potential for over-reliance on AI tools, leading to a shift in learning pathways and possible gaps in essential knowledge acquisition



### Educator Role Evolution



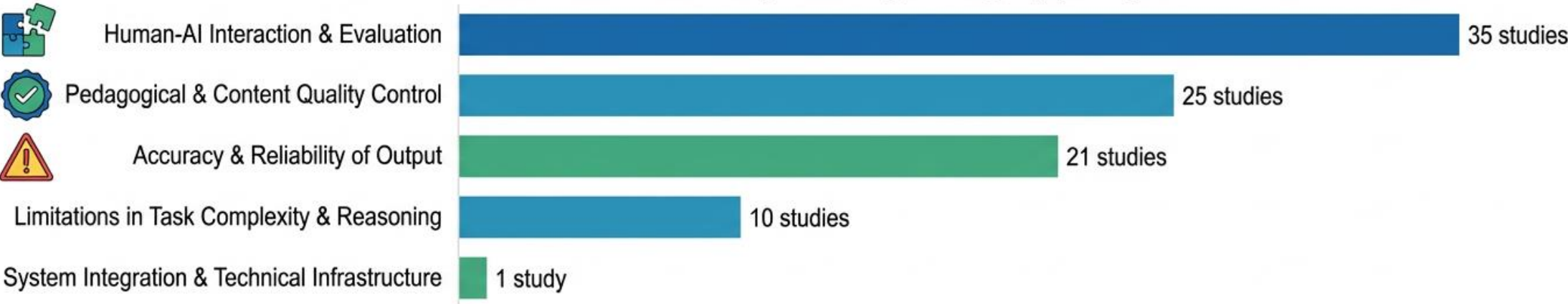




# IV. Results

## Challenges and Limitations in Human-AI Collaboration (RQ4)

Distribution of Studies by Challenge Category (n=94)



### Human-AI Interaction & Evaluation (n=35)

**Exemplar Challenges**

- Over-reliance on AI
- Lack of critical engagement
- Difficulty in prompt engineering
- Misinterpretation of AI feedback
- Ethical considerations in interaction

**Brief Description**

Focuses on how students and educators interact with AI, including issues of trust, dependence, and the effectiveness of communication and evaluation processes.

### Pedagogical & Content Quality Control (n=25)

**Exemplar Challenges**

- Ensuring alignment with learning objectives
- Maintaining academic integrity
- Preventing plagiarism
- Evaluating AI's pedagogical approach
- Difficulty in assessing original thought

**Brief Description**

Concerns the integration of AI in a way that supports educational goals, maintains standards, and ensures the quality and relevance of the content provided by the AI.

### Accuracy & Reliability of Output (n=21)

**Exemplar Challenges**

- Hallucinations (generating fabricated information)
- Inaccurate code snippets
- Factual errors in STEM concepts
- Inconsistent responses
- Bias in generated content

**Brief Description**

Issues concerning factual correctness, consistency, and trustworthiness of the content generated by the LLM, particularly in scientific and technical domains.

### Limitations in Task Complexity & Reasoning (n=10)

**Exemplar Challenges**

- Inability to solve multi-step complex problems
- Limited understanding of deep domain-specific knowledge
- Failure in abstract reasoning
- Difficulty with open-ended creative tasks
- Lack of contextual understanding

**Brief Description**

Highlights the current boundaries of LLMs in handling sophisticated STEM tasks that require deep understanding, multi-layered reasoning, and complex problem-solving capabilities.

### System Integration & Technical Infrastructure (n=1)

**Exemplar Challenges**

- Platform incompatibility with existing LMS
- Technical glitches and downtime
- High computational costs
- Data privacy and security concerns
- Limited access to advanced models

**Brief Description**

Addresses the technical and logistical hurdles in integrating AI tools into existing educational systems, including platform compatibility, cost, and data security issues.



## V. Conclusion and Future Work

### **Current Landscapes:**

- Adoption of GenAI is dominated by "human-in-the-loop" model
- LLMs primarily as tutors/assistants to enhance learning performance;
- Humans as critical evaluators for quality and accuracy.

### **Transformative Shift:**

- Emerging models position AI as a co-creator/partner, fostering higher-order cognitive skills (e.g., problem-solving, creativity) essential for STEM.



## V. Conclusion and Future Work

### **Role Evolution:**

- Students transition from passive recipients to active agents and prompt engineers;
- Educators become facilitators and designers of AI-augmented environments.

### **Challenges:**

- Technical issues (accuracy, reliability, task complexity)
- Pedagogical concerns (content quality, over-reliance)
- Need for better integration and evaluation methods.



## V. Conclusion and Future Work

### **Future Directions:**

- Prioritize longitudinal studies on sustained impacts (e.g., long-term skill development, career preparedness).
- Conduct comparative analyses of models (e.g., AI Tutor vs. AI Partner).
- Develop robust frameworks for GenAI as a transformative educational partner.
- Emphasize rigorous, large-scale experimental research beyond exploratory studies.

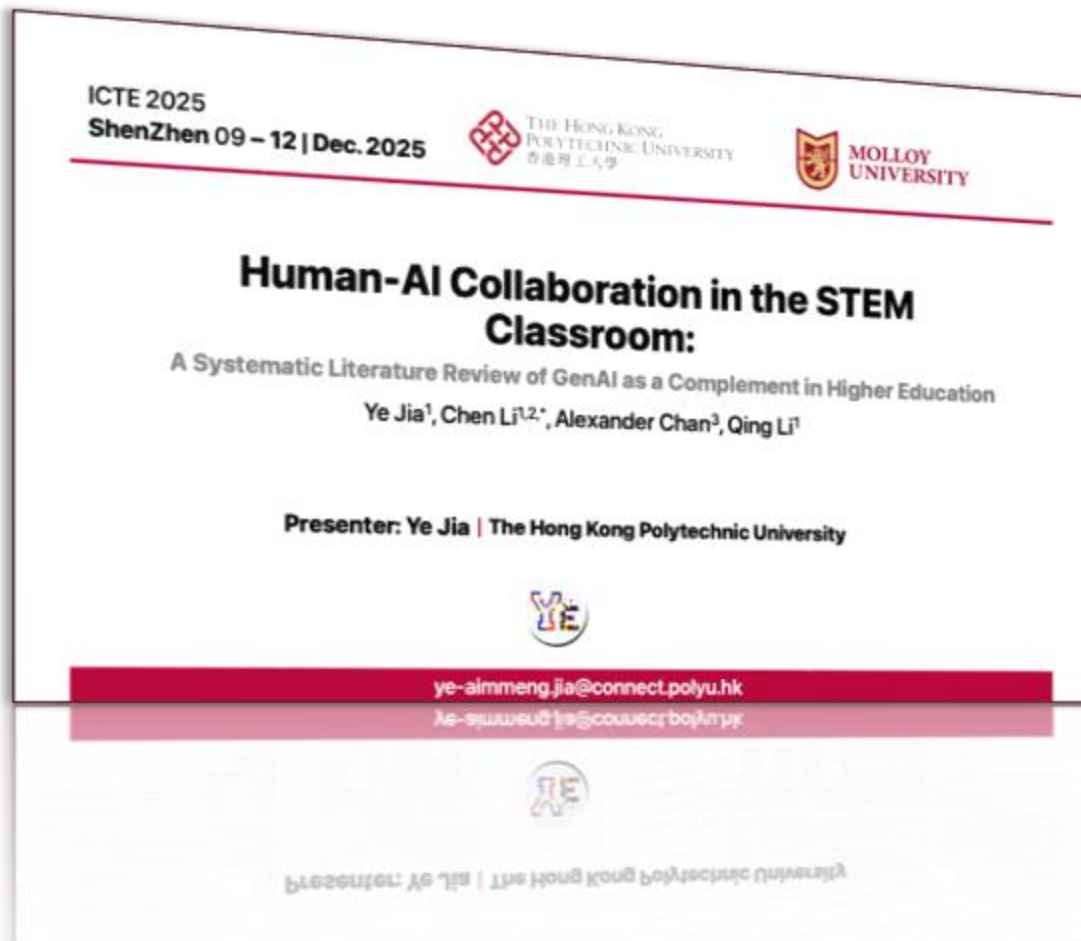


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