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Designing a Computer-Supported Collaborative Argumentation Learning Environment to Counteract Misinformation in Socio-Scientific Issues

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Abstract: This paper details the design-based research of a Computer-Supported Collaborative Argumentation (CSCA) environment to help secondary school students counter misinformation in socio-scientific issues. A pilot study revealed challenges in students' warrant articulation, source evaluation, and collaborative dynamics. These findings informed an iterative refinement of the design, which now incorporates structured protocols for systematic fact-checking and scripted, rotating roles to balance discourse. This work offers evidence-based design principles for integrating argumentation with misinformation literacy and proposes a refined pedagogical model for further testing.

Keywords: Computer-Supported Collaborative Argumentation, misinformation

1. Introduction and Background

Misinformation in complex socio-scientific issues (SSIs) presents a challenge that individual fact-checking fails to address, lacking the collaborative negotiation of meaning vital for deep learning (McBrayer, 2020; Mercier & Sperber, 2017). Computer-Supported Collaborative Argumentation (CSCA) offers a promising pedagogical model, using tools like argument maps grounded in Toulmin's Argument Model (Erduran, Simon, & Osborne, 2004; Toulmin, 2003) to structure evidence-based dialogue (Noroozi et al., 2012; Scheuer et al., 2010). By externalizing the structure of an argument, CSCA helps learners clarify their reasoning and identify weaknesses.

However, most CSCA frameworks focus on argument structure, assuming the quality of information sources rather than explicitly building skills for navigating SSIs (Seyler & Brizee, 2023). This overlooks the need for socioscientific reasoning, the ability to recognize complexity, take multiple perspectives, and exhibit skepticism, which is essential for countering misinformation that exploits cognitive and social biases (Sadler, Barab, & Scott, 2007; Ecker et al., 2022). This study addresses that gap by employing a design-based research approach to develop and pilot a CSCA environment that intentionally integrates argumentation with misinformation detection. The authors investigate how a learning environment designed to scaffold structured argumentation, source evaluation, and collaborative knowledge building can shape students' ability to critically evaluate and detect misinformation.

2. Study Design

Employing a design-based research (DBR) framework (Sandoval, 2014), a pilot study was conducted with six secondary school students (ages 11–15; 4 female, 2 male) from diverse socio-economic backgrounds in Mumbai, India, who collaborated on the polarized SSI of homeopathy. The initial design was guided by a conjecture map (Figure 1) linking design elements to intended outcomes. The multi-stage intervention, conducted in a single 120-

minute session, included pre/post assessments (Ernst, 2016; Frey et al., 2015), an individual analysis phase with guiding questions (Paul & Elder, 2019), and a core collaborative argument mapping task on the Miro platform using a Toulmin-based template. Data included interaction transcripts, argument maps, and interviews. For this paper, the verbal discourse was analyzed using a coding framework deductively derived from theories of Argument Structure (Erduran, Simon, & Osborne, 2004), Socioscientific Reasoning (Sadler, Barab, & Scott, 2007), Misinformation Detection (Ecker et al., 2022), and Collaborative Processes (Weinberger & Fischer, 2006).

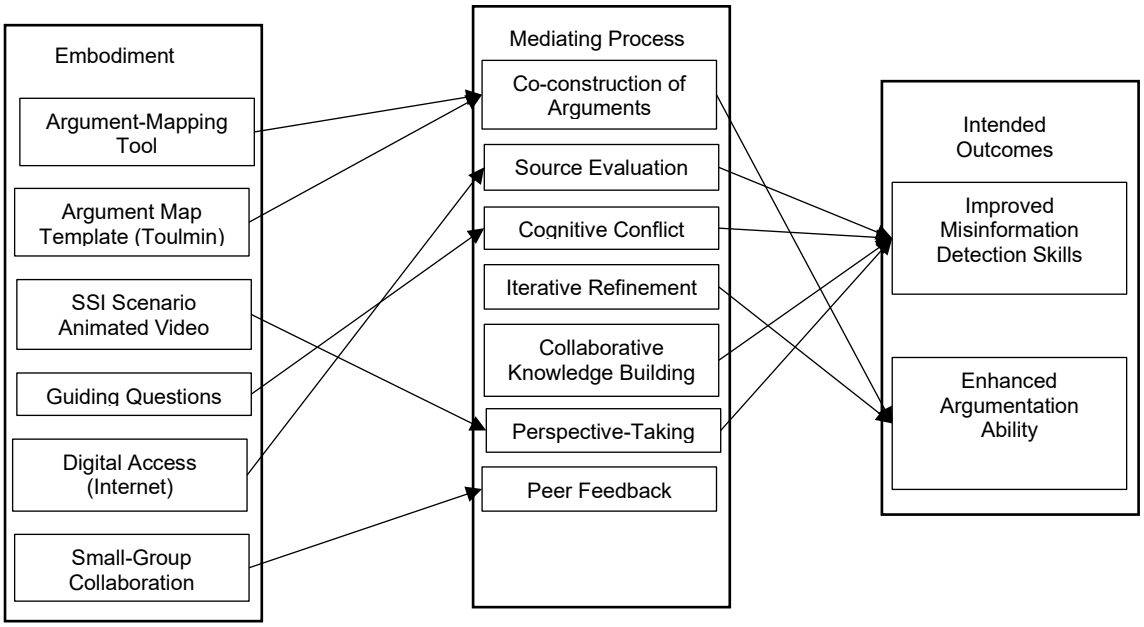

Figure 1. Initial Conjecture Map.

3. Findings and Analysis

Analysis of the discourse revealed three key challenges. First, while students could formulate Claims, they struggled with Argument Structure, particularly constructing robust Warrants. This led them to default to surface-level rebuttals rather than engaging with the scientific Complexity of the SSI (Sadler, Barab, & Scott, 2007). The group's uncertainty about what a warrant is required facilitator intervention:

Mitali (00:04:10): "Uhh what about the Warrant?"
Ananya (00:04:12): "Warrant!" (correcting pronunciation)
Facilitator (00:09:52): "Warrants are basically any assumptions made by... What they are assuming but they are not saying, right!"

Second, Misinformation Detection was reactive. Fact-Checking was limited to resolving immediate disputes rather than systematic Source Evaluation, as seen when a cost dispute was settled by a quick web search without questioning the source:

Shivam (00:11:25): "There is no significant difference between the two [costs]." (Reading from laptop)
Anuj (00:11:30): "Sometimes they are expensive ..."
Shivam (00:11:35): "It's the same price!"

This interaction exemplifies Fact-Checking without deeper Skepticism or Bias Reflection, a critical step in proactive detection (Sadler, Barab, & Scott, 2007; Ecker et al., 2022).

Third, Collaborative Processes were hindered by asymmetric Role Performance. Without structured roles, social dynamics led to Conflict-Oriented Consensus Building

(Weinberger & Fischer, 2006) and stifled Perspective-Taking, as shown when one student asserted intellectual superiority:

> Shivam (00:10:17): "I am smarter than you... You only said yourself."
> Anika (00:20:20): "Chup, nikal! Nikal!" (shut up, go away!)

Such assertions created an environment where peers were dismissed, indicating how unstructured Interaction Patterns prevented the collaborative evaluation of competing claims.

4. A Refined Design for Countering Misinformation

The pilot findings directly informed the next iteration of the DBR cycle, leading to a refined design with more robust and explicit scaffolds, as encapsulated in a revised conjecture map (Figure 2). To strengthen warrant construction, the Toulmin template was enhanced with structured prompts and bias/fallacy guides to encourage a deeper interrogation of evidence beyond surface-level rebuttals (Erduran, Simon, & Osborne, 2004). To shift students from reactive to proactive source evaluation, the design now systematizes inquiry with timed phases for applying credibility frameworks (e.g., the CRAAP test), fostering healthier skepticism and strategic information-use habits (Ecker et al., 2022; Sadler, Barab, & Scott, 2007). Finally, to mitigate social asymmetry, the refined design formalizes collaboration using scripted, rotating roles, such as "Devil's Advocate" or "Fact-Checker," to balance participation and foster more equitable interaction patterns (Kollar et al., 2007; Weinberger & Fischer, 2006). These targeted refinements represent a more theoretically grounded approach to aligning collaborative argumentation with the explicit goal of counteracting misinformation.

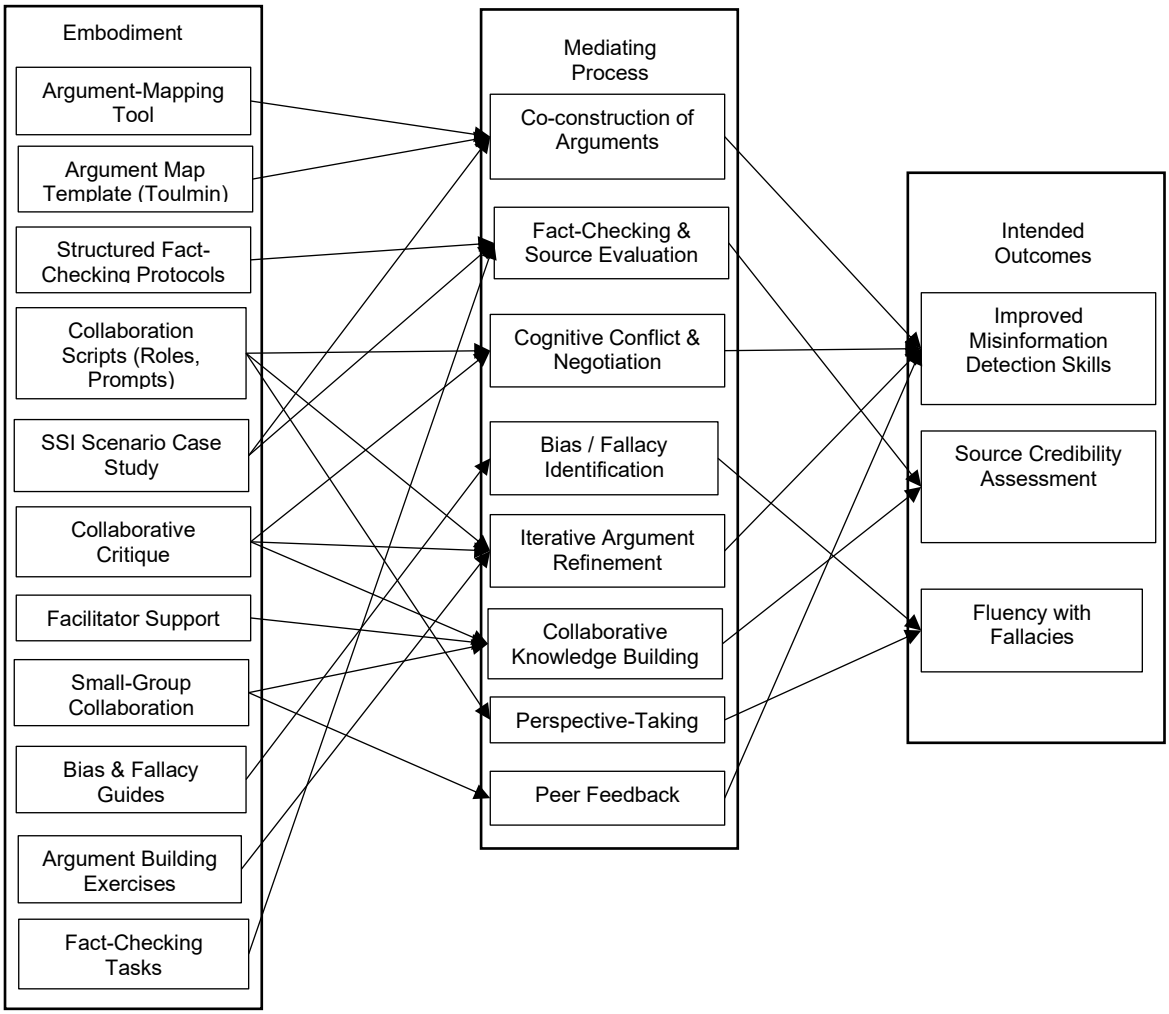

Figure 2. Revised Conjecture Map.

5. Discussion and Future Directions

The pilot study highlights a critical disconnect between structuring an argument and critically evaluating its informational foundations. While structured argument mapping supported claim formulation, it proved insufficient for fostering warrant articulation, a finding that echoes prior research (Scheuer et al., 2010). Similarly, the study revealed that unstructured collaboration can amplify social dominance and that providing internet access without clear protocols results in reactive, ad-hoc fact-checking, a gap also seen in broader misinformation interventions (Nyhan & Reifler, 2010). The persistence of cultural narratives underscores the need for CSCA designs that integrate both cognitive and socio-emotional scaffolds, moving beyond frameworks that prioritize only logical reasoning (Ecker et al., 2022; Suthers & Hundhausen, 2003). This work's primary contribution is in identifying warrant articulation and role asymmetry as critical mediators of argument quality in this context and offering practical design principles to address them.

As this is a preliminary study, the small sample size and single-cycle design limit generalizability. Therefore, future work is essential to validate and extend these findings. The immediate next step is to test the refined conjecture map and its associated protocols with larger and more diverse student cohorts (target N > 50) to establish the generalizability of the proposed design principles. Future iterations should also explore the potential for technological integration, such as AI-driven tools that can provide automated feedback, and investigate the applicability of this pedagogical model to other complex SSIs, such as climate change. By systematically aligning collaborative argumentation with proactive misinformation literacy, this research trajectory aims to develop a robust model that equips learners to navigate polarized discourse not just through isolated fact-checking, but through socially embedded critical thinking.

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