International Council on Systems Engineering
A better world through a systems approach

AI Outperforms 43 SE Graduates in Creating Causal Loop Diagrams of Janis Groupthink Phenomena (AI4ST)

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Colorado State University-Systems Engineering Dept.

Today's Agenda

- Punchline
- Author Bio
- Systems Thinking vs. Linear Compartmentalized Thinking
- Janis Groupthink Phenomena
- Workflow to create and compare CLDs (Pipeline Algebra)
- Comparison of AI vs. Grad Students in SE
- Results
- Conclusions
- Future Work

Thinking of Real-World Problems as *Systems* does not come naturally to most people!

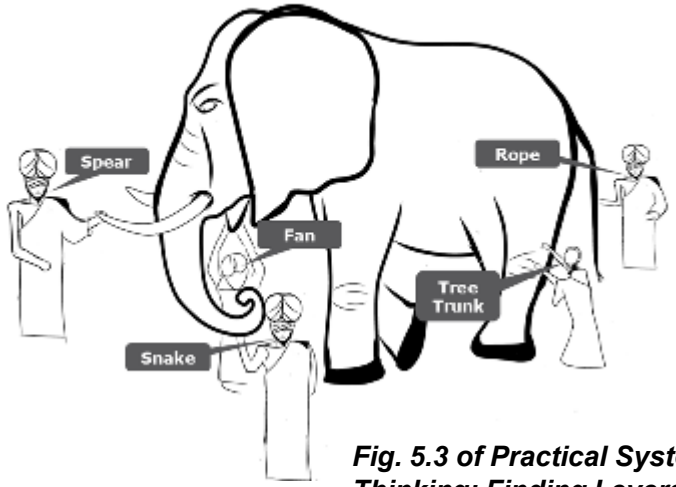


Fig. 5.3 of Practical Systems Thinking: Finding Leverage on Complex Problems (Springer)

Yet Systems Thinking and enabling Rigorous Methods are Essential for Understanding Real-World Problems.

Author Bio

Kirk Reinholtz, PhD

Kamran Eftekhari Shahroudi

PhD, INCOSE ESEP

Kirk Reinholtz

PhD

- Kirk Reinholtz earned his Ph.D. in Systems Engineering and Artificial Intelligence at Colorado State University in Summer 2025 and remains affiliated with CSU through August 2025 while finalizing publications on Pipeline Algebra, an AI-accelerated workflow language for system dynamics, and its applications. His research interests include system dynamics, causal-loop modeling, policy simulation, AI, and AI governance.
- Previously a Principal Engineer at the Jet Propulsion Laboratory, California Institute of Technology, he developed flight software now operating around Mars and en route to Jupiter. His honors include the Wolfram Innovation Award (2019) and the Java ``Duke's Choice'' Award (2003) as well as numerous NASA internal awards. He left JPL to pursue doctoral research full-time.

Education

- PhD, 2025, Colorado State University, Ft Collins
- MS Computer Science, 1996, University of Southern California

Kamran Eftekhari Shahroudi

PhD, INCOSE ESEP

Systems Fellow (Corporate Engineering, Woodward, Inc., 28+ years)

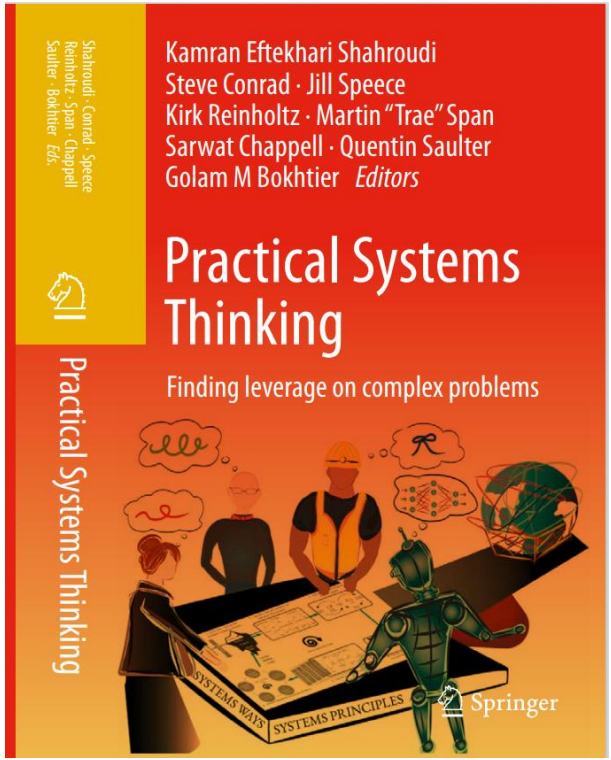
Professor of SE at Colorado State University (16+years)

Expertise

- Model-Based Systems Thinking (MBST)
- Hiring and Coaching Systems-Oriented Industry Talent
- Multi-disciplinary Systems Design Optimization with HITL
- Motion and Energy Control of Aerospace, Land, and Marine Systems

Education

- Expert Systems Engineering Professional (ESEP) 2024, INCOSE
- Post Doctoral 1997, Centrum Wiskunde & Informatica – Amsterdam
- Ph.D 1994, Delft University of Technology, Netherlands – Propulsion System Design
- Sc.M 2008, Massachusetts Institute of Technology (MIT) – Systems Design and Management
- M.S.A.E 1989, University of Michigan – Ann Arbor – Gas Dynamics
- B.Tech. 1988, Loughborough University, UK – Aeronautical Engineering & Design

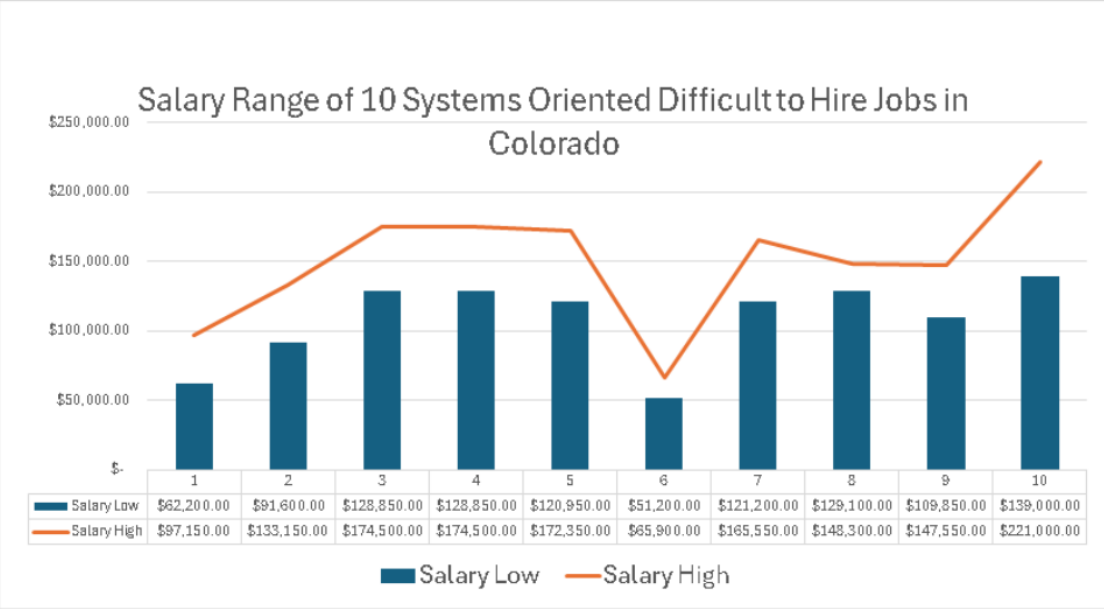


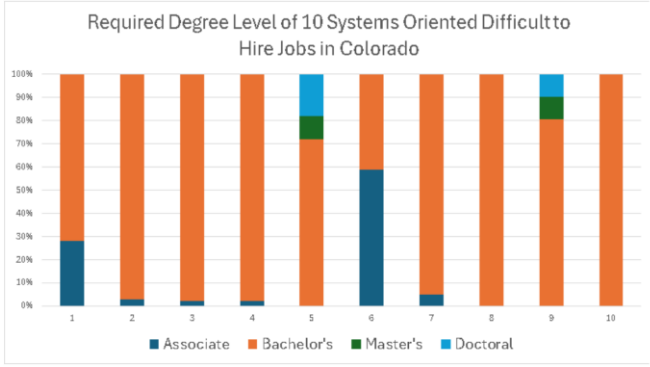
Systems Thinking vs. Linear Compartmentalized Thinking

Causal Loop Diagram vs. Fishbone to understand the real-world problem of systems-oriented skills shortage in Colorado

Shortage of Ten Systems Oriented Jobs in Colorado

2023 snapshot data collected from job announcements. Charts(Figs. 8.1,8.4, 8.5) from *Practical Systems Thinking: Finding Leverage on Complex Problems by K Eftekhari Shahroudi et. Al.*

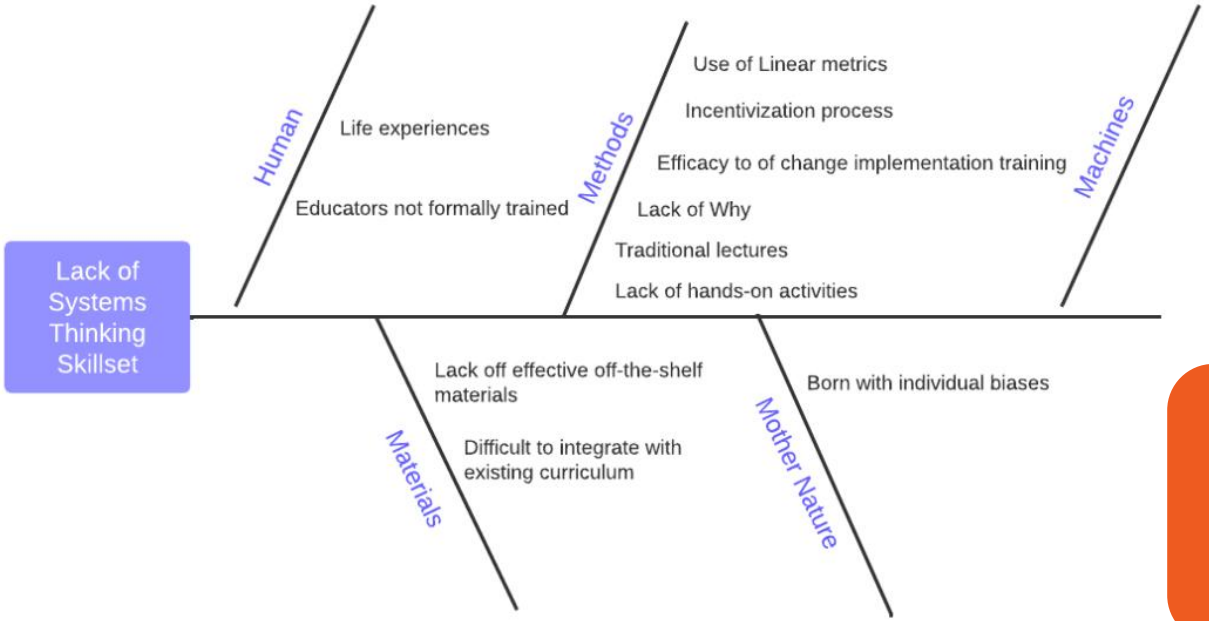




Shortage of Available Talent for High Paying Low Barrier to Entry Jobs!

Linear Compartmentalized Understanding of ST Skills Shortage

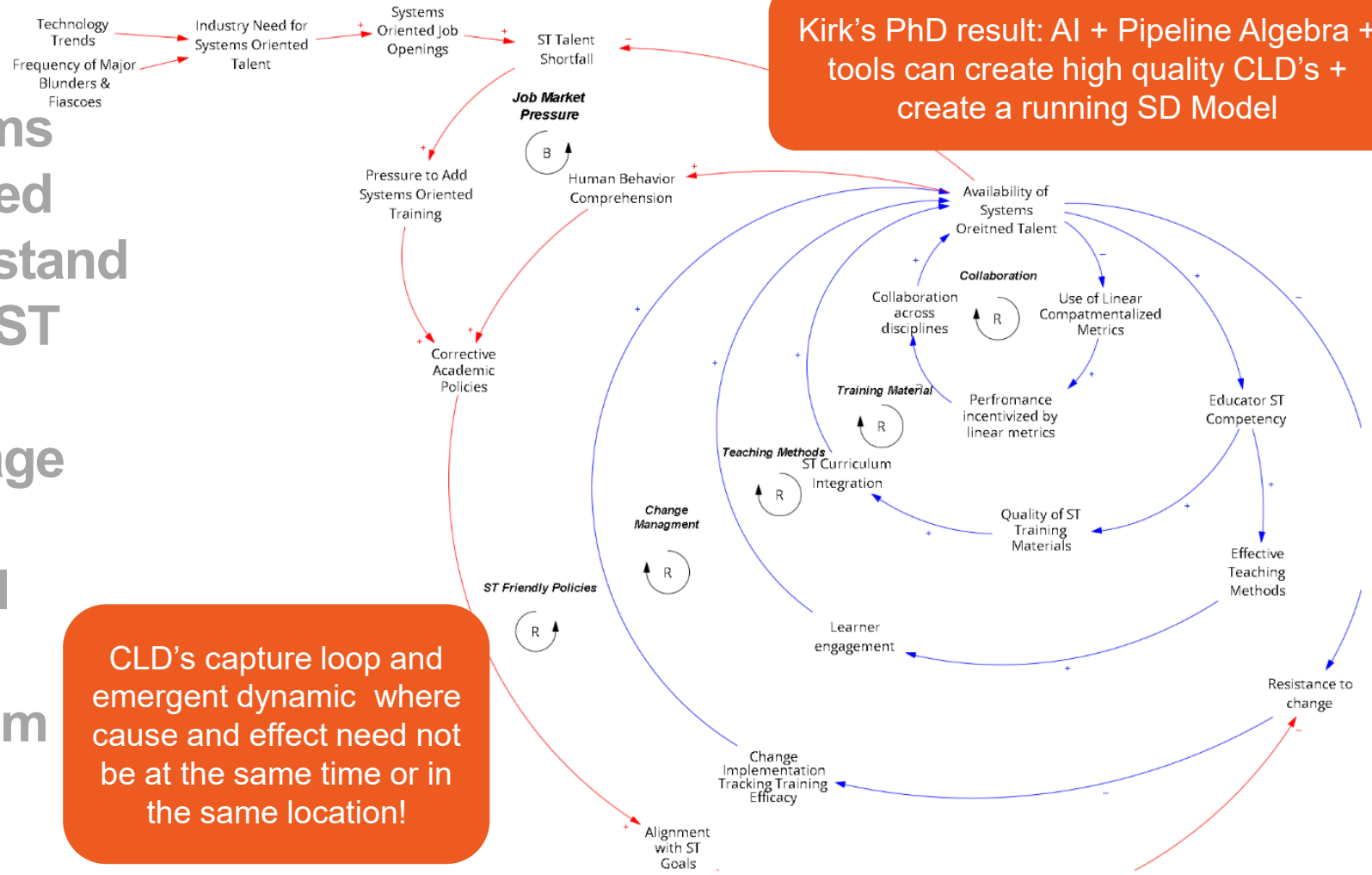
Fishbone (Fig. 8.7) from *Practical Systems Thinking: Finding Leverage on Complex Problems by K Eftekhari Shahroudi et. Al.*



Fishbone is a good start but typically used in linear compartmentalized thinking

Systems Oriented Understanding of ST Skills Shortage Using Causal Loop Diagram (CLD)

Kirk's PhD result: AI + Pipeline Algebra + tools can create high quality CLD's + create a running SD Model



CLD's capture loop and emergent dynamic where cause and effect need not be at the same time or in the same location!

CLD (Fig 8.8) from *Practical Systems Thinking: Finding Leverage on Complex Problems by K Eftekhari Shahroudi et. Al.*

Using AI to Help Understand Janis Groupthink Phenomena

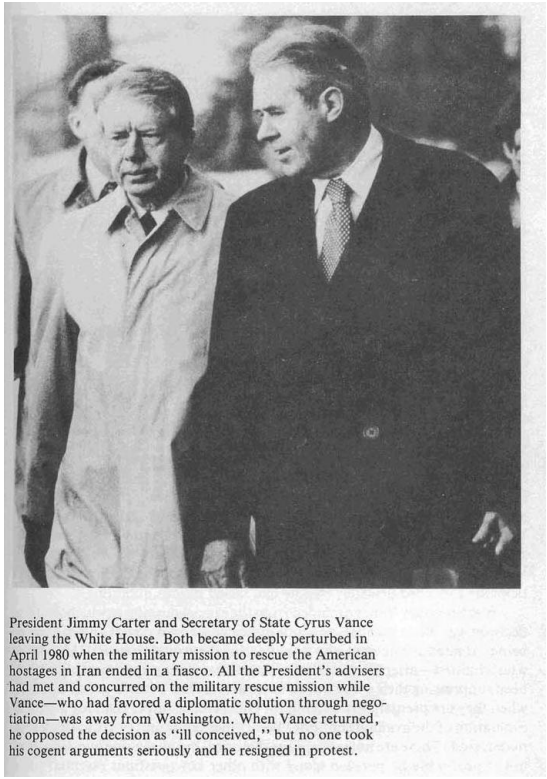
This section used Google Gemini 2.5

Given a partially complete CLD of groupthink, find additional causal relations and loops implied by the Janis article.

Using standard out-of-the-box Gemini 2.5 and Grok 3

The Groupthink Syndrome

Pictures from Janis, I. L. (1982). *Groupthink : psychological studies of policy decisions and fiascoes* (2nd ed.). Houghton Mifflin.



President Jimmy Carter and Secretary of State Cyrus Vance leaving the White House. Both became deeply perturbed in April 1980 when the military mission to rescue the American hostages in Iran ended in a fiasco. All the President's advisers had met and concurred on the military rescue mission while Vance—who had favored a diplomatic solution through negotiation—was away from Washington. When Vance returned, he opposed the decision as "ill conceived," but no one took his cogent arguments seriously and he resigned in protest.

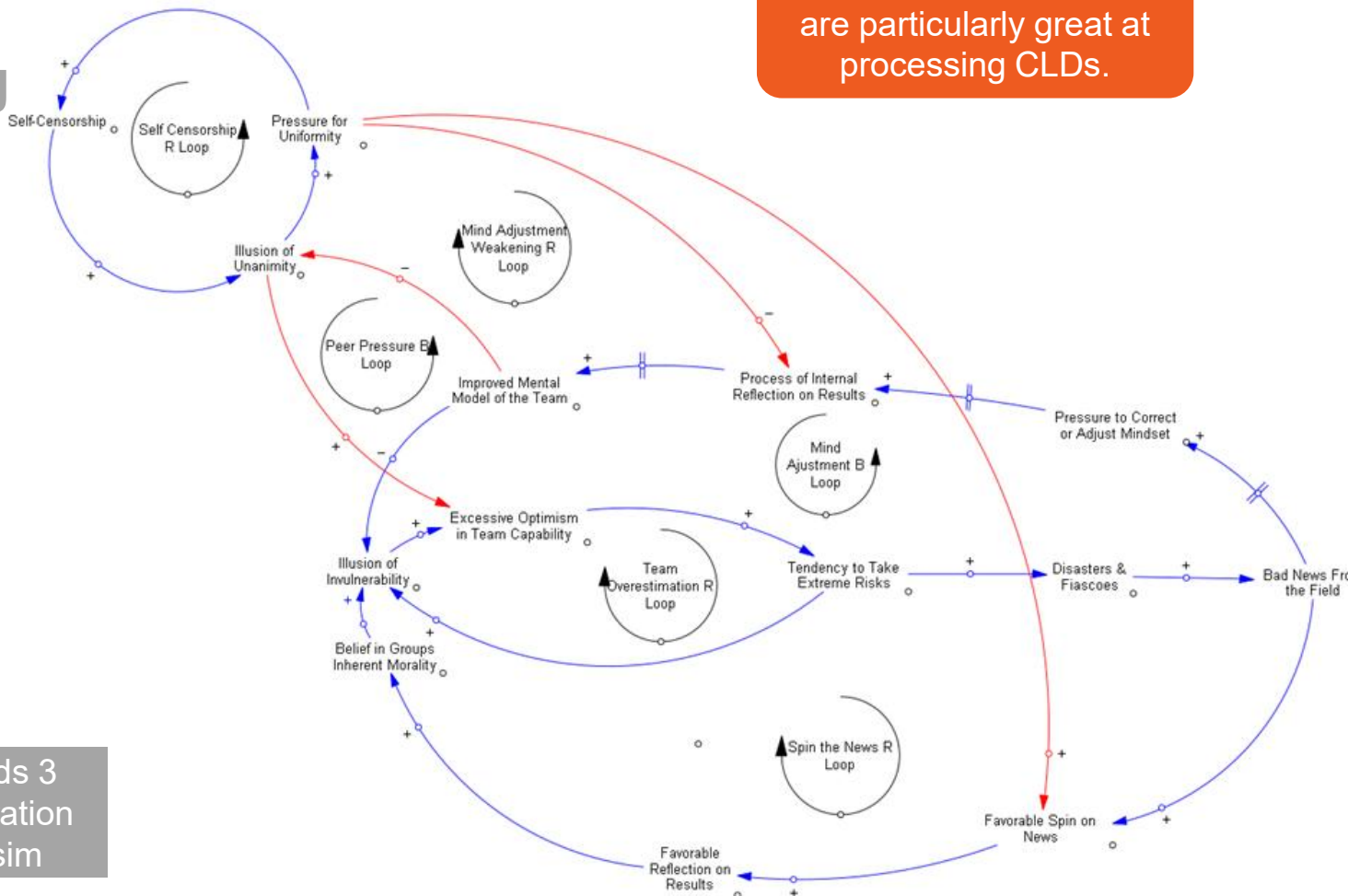
In Munich, September 1938, Chancellor Hitler and Prime Minister Chamberlain shake hands after concluding the "Peace of Munich." Next to Chamberlain is Sir Neville Henderson, Britain's ambassador to Germany.

SE Graduate taking the SYSE 505 & 532 try to create CLDs for the Groupthink Syndrome from this article.

Using AI to Find Missing or Ignored Loops in CLDs

Input Vensim model (text of .mdl file) of the lower 3 Loops (in Blue) + prompt to identify missing loops that are directly explained or implied in the Janis Article. Gemini found the missing loops. Human created the drawing of the loops using Vensim.

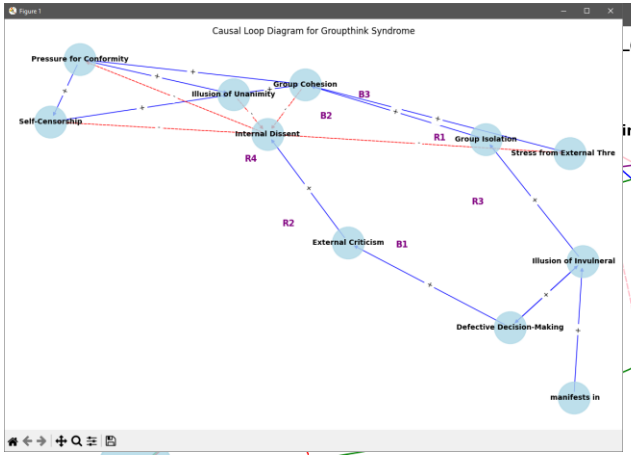
Discovered that LLMs are particularly great at processing CLDs.



Google Gemini 2.5 adds 3 Upper Loops. Transliteration of text to CLD in Vensim

Using AI to Create CLDs from Scratch

Input prompt: Identify at Least 3 B Loops and 4 R Loops in the Janis Groupthink Syndrome. Create a python code to draw the CLD.

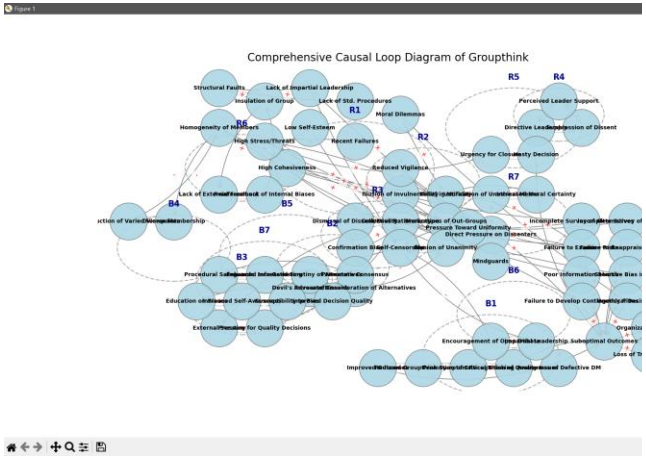


Grok 3 Quickly identified and Created CLD with straight and Curvy Edges

But Causal relations are typically distributed among a vast set of documents.

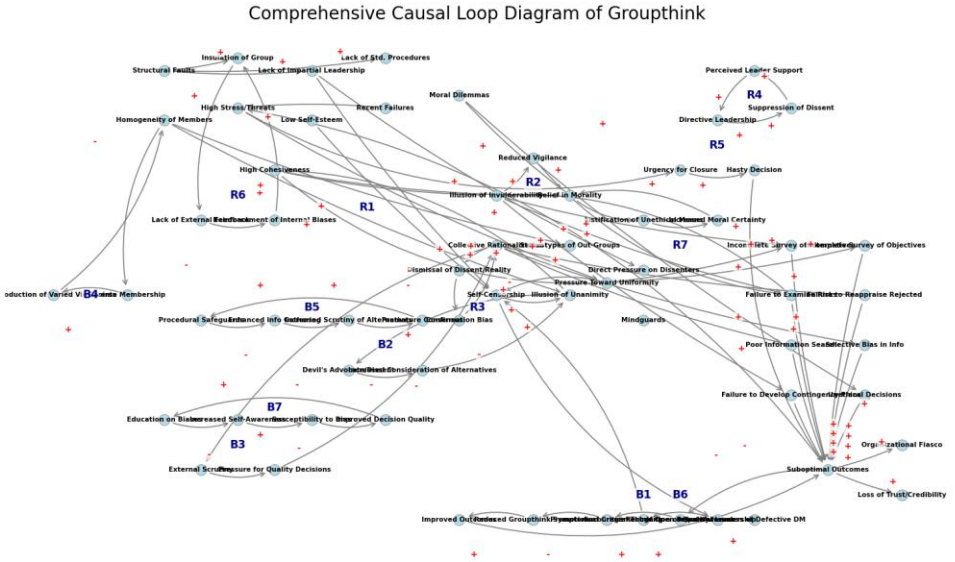
Using AI to Create CLDs from Scratch

Input prompt: Extract a comprehensive Causal Loop Diagram from 50 top cited articles on Groupthink. Create a Python code to draw the CLD



Google Gemini 2.5 extracts a more comprehensive CLD from top cited articles on groupthink.

Reduce node size and ensure causal arrows within a loop do not cross for human readability



Question: how does AI perform Vs. SE Students midway thru the semester.

Automated generation of CLDs and comparison with grad students

Automated comparison of AI with SE Grad students

Pipeline Algebra (new, ours)
OpenAI ChatGPT4(o1 and o1 pro) 3/2025
Computations in Wolfram Mathematica
Vensim (Ventana Systems) for Manual Transliteration
Body text and narrative arc human-generated

Quantitative Measures

Apple to apple comparison

- Vertex Count
- Edge Count
- Loop Count
- Count of Vertices in Loops
- Loop count with triangular redundancies removed
  - A->B, B->C and A->C

Apple to Apple Comparison

Other Tools

- Wolfram Mathematica
- Vensim PLE

Computation and Visualization

Automation: Pipeline Algebra

– NOTE some details elided
– NOTE Iterative prompting used to maximize TPU*s applied to CLD discove

$$(f \circ g)(x) \equiv f(g(x))$$
$$\text{Map}(f)\{a, b, c, \ldots\} \equiv \{f(a), f(b), f(c), \ldots\}$$
$$\text{Comap}(\{f, g\})(x) \equiv \{f(x), g(x)\}$$
$$\text{Doprompt}($$
$$\quad \text{Key}(P_{problemstmt})$$
$$\quad \text{Session} \rightarrow \text{Autonomous},$$
$$\quad \text{Endpoint} \rightarrow "chatgpt - o1"$$
$$) \xrightarrow{\text{insert}} L_{problemstmt}$$
$$\circ \text{ExpandTemplate}($$
$$\quad \text{Key}(T_{base}),$$
$$\quad \{prompt \mapsto \ldots, article \mapsto \text{Key}(myarticle)\},$$
$$) \xrightarrow{\text{insert}} P_{problemstmt}$$
$$\circ \text{Set}(\{T_{base} \mapsto \ldots, myarticle \mapsto \ldots, G_{smecld} \mapsto \ldots, F_1 \mapsto \ldots, F_2 \mapsto \ldots\})(\varnothing)$$

NOTES:
1. Hungarian notation used to improve readability:
   $A \mapsto$ kvmap
   $F_{name} \mapsto$ File name
   $G_{name} \mapsto$ ADG
   $J_{name} \mapsto$ JSON string or struct

Workflow and Leverage of Interconnected AI and other Tools

Figure 5. Pipeline Algebra Example.

Workflow for Comparison

Programmed in Pipeline Algebra (PA)

This is a visualization of PA used to leverage AI to compare CLDs

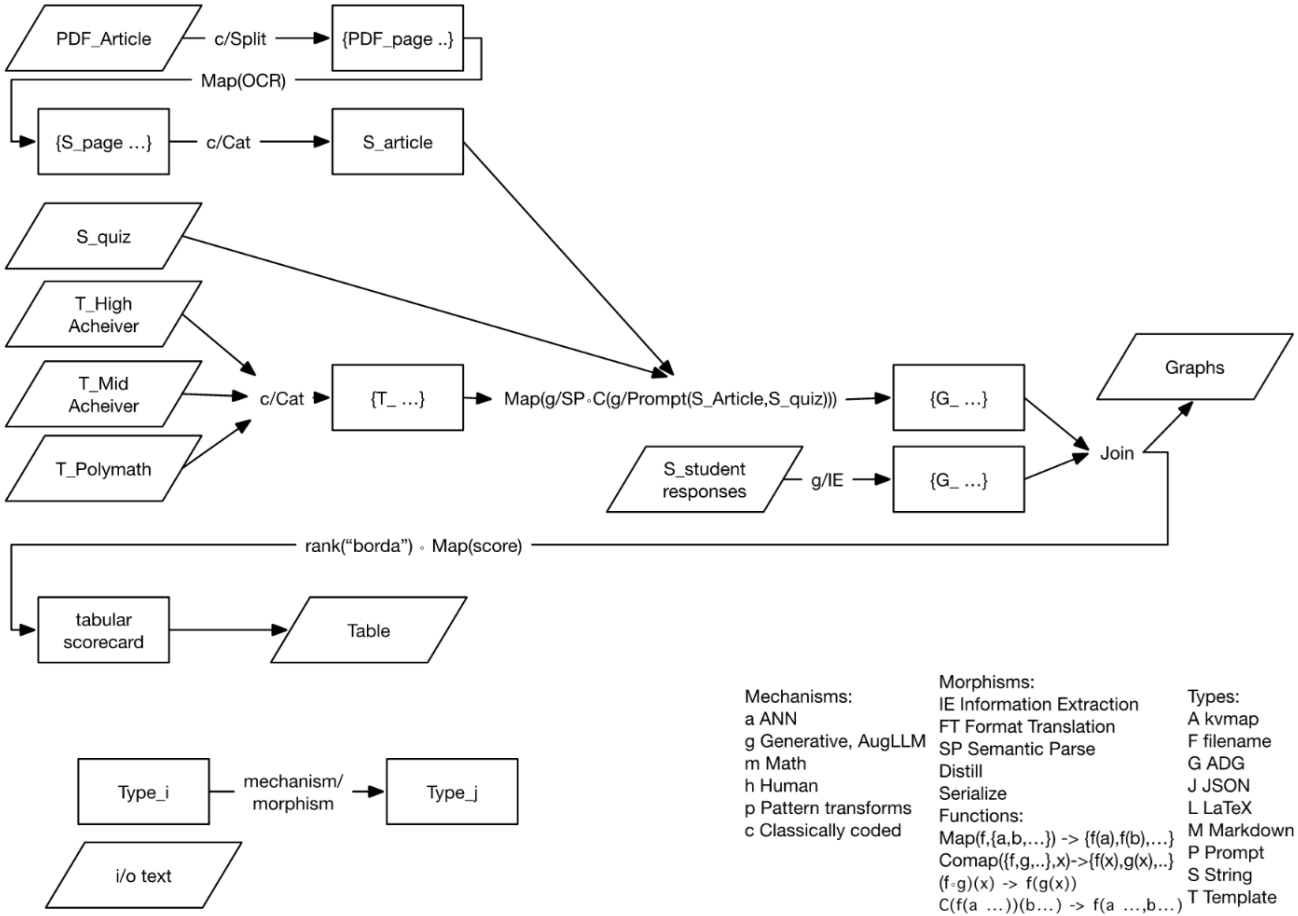
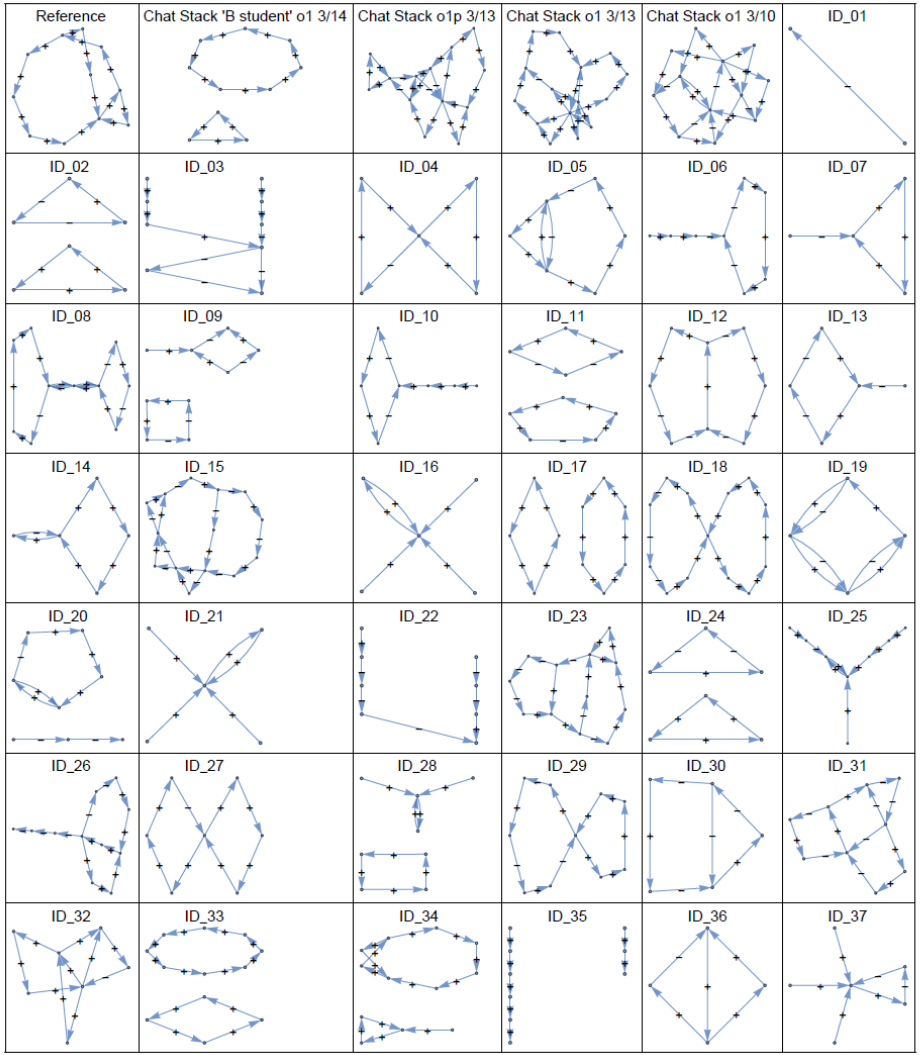


Figure 4. Morphisms and Operators.

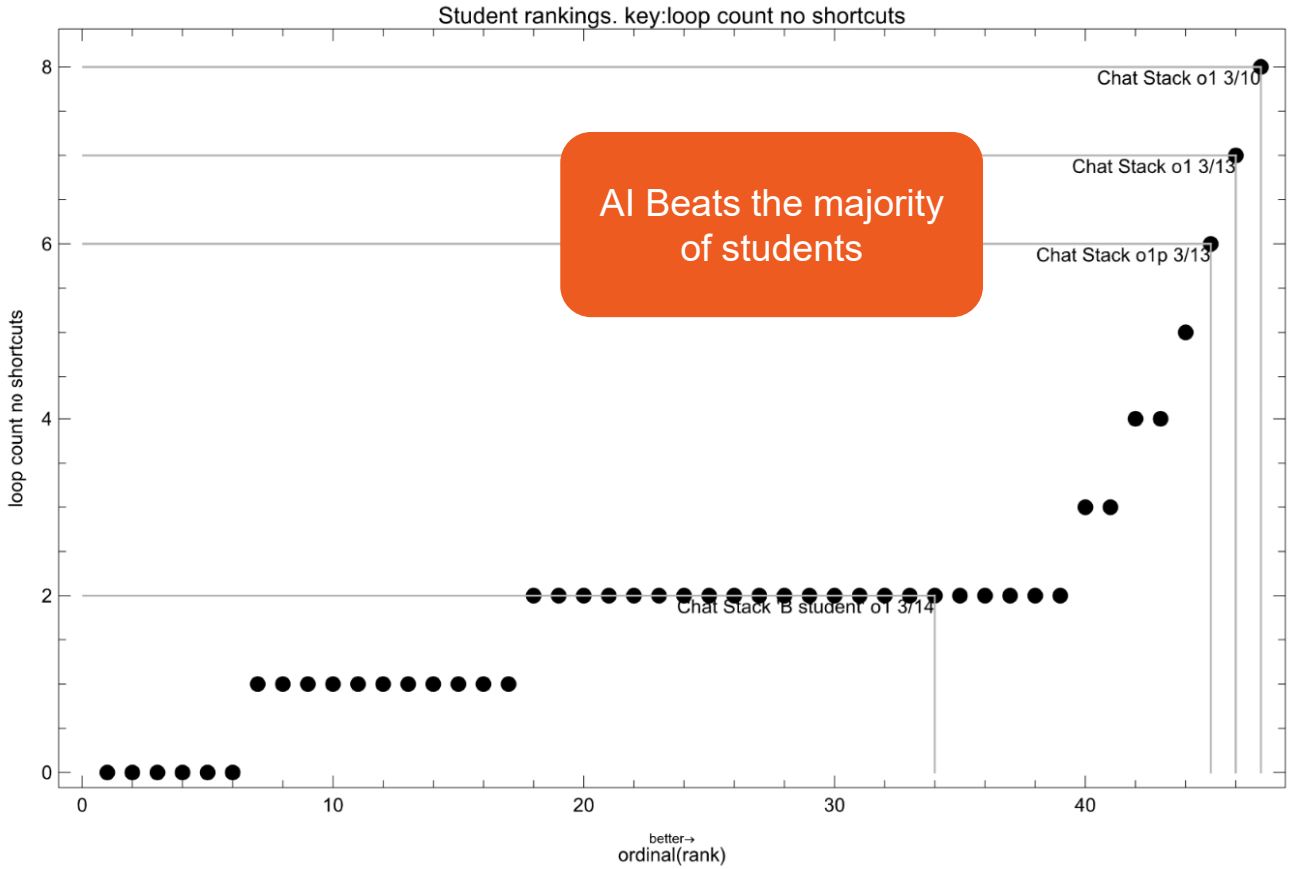
Results

CLDs of Students Versus AI

Note a significant # of students have a very hard time shedding their linear mindset!



Loop count Comparison



Comparison Table

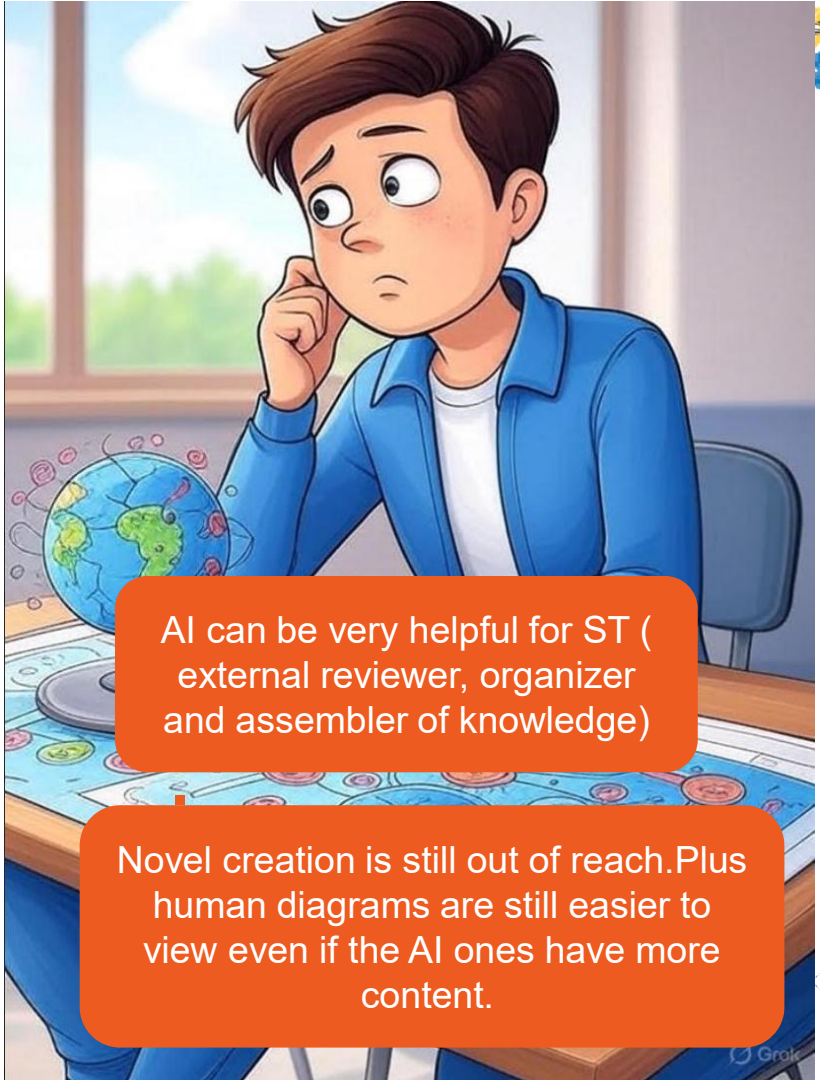
Table 1. Student Rankings, tabular.

id	RANK (Borda)	loop count rank	loop count no shortcuts rank	vertex count	edge count	loop count	vertices in cycles count	closure2 count	loop count no shortcuts
Chat Stack o1 3/10	93	46	47	12	20	13	12	2	8
Chat Stack o1p 3/13	90	45	45	13	20	12	13	2	6
Chat Stack o1 3/13	90	44	46	15	21	8	15	1	7
ID_23	86	42	44	12	15	5	12	0	5
ID_31	84	41	43	9	12	4	9	0	4
ID_08	82	40	42	10	13	4	10	0	4
ID_34	79	38	41	12	13	3	11	0	3
ID_32	78	43	35	7	10	5	7	2	2
Reference	77	37	40	11	13	3	11	0	3
ID_42	75	36	39	7	7	2	7	0	2
ID_40	72	34	38	6	7	2	5	0	2
ID_15	72	47	25	14	18	16	14	3	2
ID_36	70	33	37	5	5	2	4	0	2
ID_33	68	32	36	12	12	2	12	0	2
ID_30	65	31	34	5	6	2	5	0	2
ID_29	63	30	33	10	11	2	10	0	2
ID_28	61	29	32	8	8	2	6	0	2
ID_05	60	39	21	6	8	4	6	1	2
ID_27	59	28	31	7	8	2	7	0	2
ID_26	57	27	30	11	12	2	8	0	2
ID_24	55	26	29	6	6	2	[illegible]	[illegible]	2
ID_20	53	25	28	8	8	2	[illegible]	[illegible]	2
ID_41	52	35	17	6	7	2	[illegible]	[illegible]	1
ID_18	51	24	27	13	14	2	[illegible]	[illegible]	2
ID_17	49	23	26	10	10	2	[illegible]	[illegible]	2
ID_14	46	22	24	5	6	2	[illegible]	[illegible]	2
ID_12	44	21	23	8	9	2	[illegible]	[illegible]	2
ID_11	42	20	22	9	9	2	[illegible]	[illegible]	2
ID_04	39	19	20	5	6	2	[illegible]	[illegible]	2
ID_02	37	18	19	6	6	2	[illegible]	[illegible]	2
Chat Stack 'B student' o1 3/14	35	17	18	10	10	2	[illegible]	[illegible]	2
ID_37	32	16	16	6	6	1	3	0	1
ID_25	30	15	15	8	8	1	2	0	1
ID_21	28	14	14	5	5	1	2	0	1
ID_19	26	13	13	4	7	1	4	0	1
ID_16	24	12	12	5	5	1	2	0	1
ID_13	22	11	11	5	5	1	4	0	1
ID_10	20	10	10	7	7	1	4	0	1
ID_09	18	9	9	9	9	1	4	0	1
ID_07	16	8	8	4	4	1	3	0	1
ID_06	14	7	7	8	8	1	5	0	1
ID_39	12	6	6	7	6	0	0	0	0
ID_38	10	5	5	10	9	0	0	0	0
ID_35	8	4	4	9	7	0	0	0	0
ID_22	6	3	3	8	7	0	0	0	0
ID_03	4	2	2	10	9	0	0	1	0
ID_01	2	1	1	2	1	0	0	0	0

AI Beats the students in all metrics except vertices in cycles count

Conclusions

- Real-world problems are getting harder
- Linear/Compartmentalized thinking is limited
- System Thinking improves our odds
- But it also does not come naturally to most people
- AI integrates very well with rigorous tools for ST
  - CLDs and by extrapolation SD models
  - Novices get a fast and relevant start
  - Experts get efficiency + missing loops
- Today, we need special tools to leverage AI for ST
  - e.g. Pipeline Algebra
- But AI will likely learn to embed tools like PA



Detailed Findings

AI integration enables ST

- Aug-LLM understands and generates high-quality CLD's
- Easy extraction of causal relations buried in the literature
- Significant help to practitioners
- Can attenuate its performance to B-level!

Benefits: ST experts and learners

- Rapid generation of quality models understandable by humans and machines
- Tool Vendors integrate Aug-LLM into rigorous tools to simplify ST work
- Application to Education, Policy Analysis, and Real-World Problems

V&V is difficult

- LLMs are stochastic and evolve
- Labor-intensive without special tools like Pipeline Algebra to automate workflows
- LLMs hallucinate unpredictably

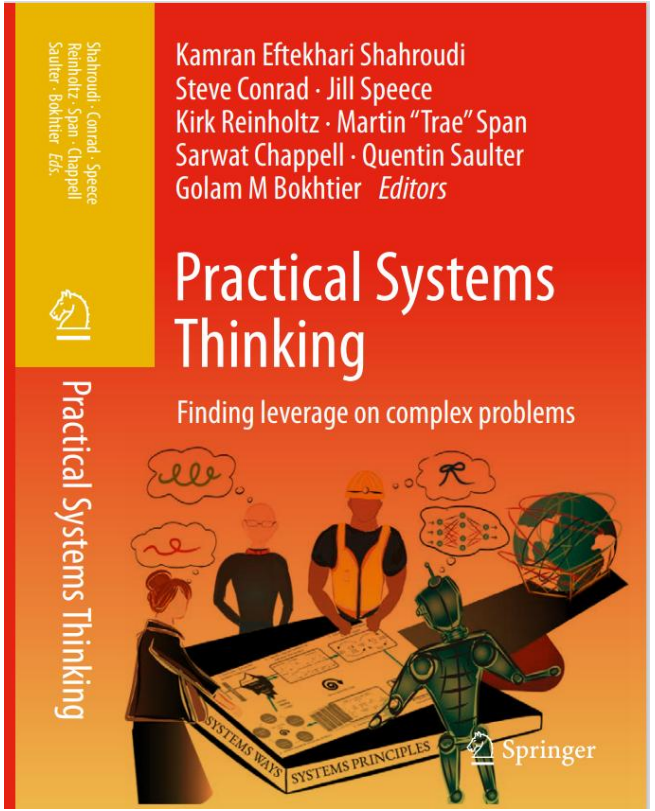
For SE's and Non-SE's!

Future Work

The future is here already, please read Kirk Reinholtz's PhD thesis: HUMAN GUIDED, AI-ACCELERATED SYSTEM DYNAMICS VIA PIPELINE ALGEBRA (Available from Proquest shortly)

Validated System Dynamics Models

- Utilization of a database of 1000+ SD models
- Create corpus of reference mode data from open sources and literature
- Creating SD models from CLDs
- Auto-fit of SD model to Refmode data
- Auto identification of causal link and loop polarity
- Auto identification of dominant loops
- .. All accelerated with HITL Agentic AI coordinated with PA



Backup Slides

SYSE 505/532 Class Assignment on

Groupthink Class Participation

Class Participation Discussion

Read Janis's Paper on Groupthink

- Think About the Dynamic Phenomena is this paper
  1- Give a high-level description of the loops or dynamic effects?
  2- Draw at least one "Viscous" loop? This is a loop that is hurting the organization: i.e. increase disasters or fiascoes due to groupthink.
  3- Draw at least one "Virtuous" loop? This is a loop that helps the organization avoid groupthink and reduce disasters or fiascoes.

(Note: when drawing each loop, make sure causal arrows have signs, loops are named and identified R or B).