Modeling the Processes of Diagramming Arguments that Support and Inhibit Students’ Understanding of Complex Arguments

By Allan Jeong & Haeyoung Kim

Abstract: Research on the efficacy of diagramming complex arguments has been mixed (Braak, 2006). One reason for the mixed findings is that the processes students use to successfully construct an argument diagram have yet to be fully examined. This correlational study tested a set of tools and methods to record, sequentially analyze, and identify sequential patterns in argument diagramming actions performed by graduate-level students that created high and low quality diagrams. Transitional state diagrams were created to reveal sequential patterns in students’ actions and to reveal action sequences that were unique among high vs. low performing students - processes that are believed to either help or inhibit students’ ability to construct accurate argument diagrams and achieve a better understanding of complex arguments. The findings reveal processes that in the future can be embedded into diagramming software to test how particular processes affect students’ ability to analyze and better understand complex arguments.

Purpose

Research on the efficacy of using visual diagramming tools to facilitate argument analysis has been mixed (Braak et al., 2006). One reason for the mixed findings is that no empirical studies have yet been conducted to formally identify the sequential steps (and underlying reasoning processes) students use when constructing argument diagrams. This study tested a set of visual analytic software tools and methods to record, sequentially analyze, visualize, identify and compare sequential patterns in argument diagramming actions performed by graduate-level students that created high and low quality argument diagrams. Transitional state diagrams were then created and used to visualize sequential patterns found in the actions of students that created high and low quality argument diagrams. The transitional state diagrams were then compared to reveal action sequences that were used by high performing students, but not used by low performing students and vice versa. The unique action sequences performed only by the high performing students can reveal the types of diagramming processes that can be promoted, taught, and scaffolded to help students construct more accurate argument diagrams and improve students’ understanding of complex arguments.

Introduction

Critical thinking is an important skill that enables one to accurately reason and judge information and become lifelong learners for the 21st century. It has been defined as ‘the art of analyzing and evaluating thinking with a view to improving it’ (Paul & Elder, 2001) and an intellectual standard that includes clarity, accuracy, precision, relevance, depth, logic, and breadth (Mclean, 2005). However, recent research suggests that many college students fail to develop critical thinking skills to the extent that they can effectively use them (Kuhn, 1991). To address this problem, various methods have been used in higher education to teach students the skills of argumentation and argument analysis across many disciplines. Argument analysis is the study of logical relationships between propositions presented in an argument (which can be mutually supporting or opposing opinions/claims) in order to reason through premises to reach a conclusion. In argument analysis, students identify the functional roles of each proposition (i.e., conclusion, premise, co-premise, counterargument), analyze the hierarchical relationship among propositions (i.e., levels of premise), and evaluate the quality and line of reasoning. This process helps students to correctly judge the quality and identify flaws within an argument and help students to make well-reasoned decisions.

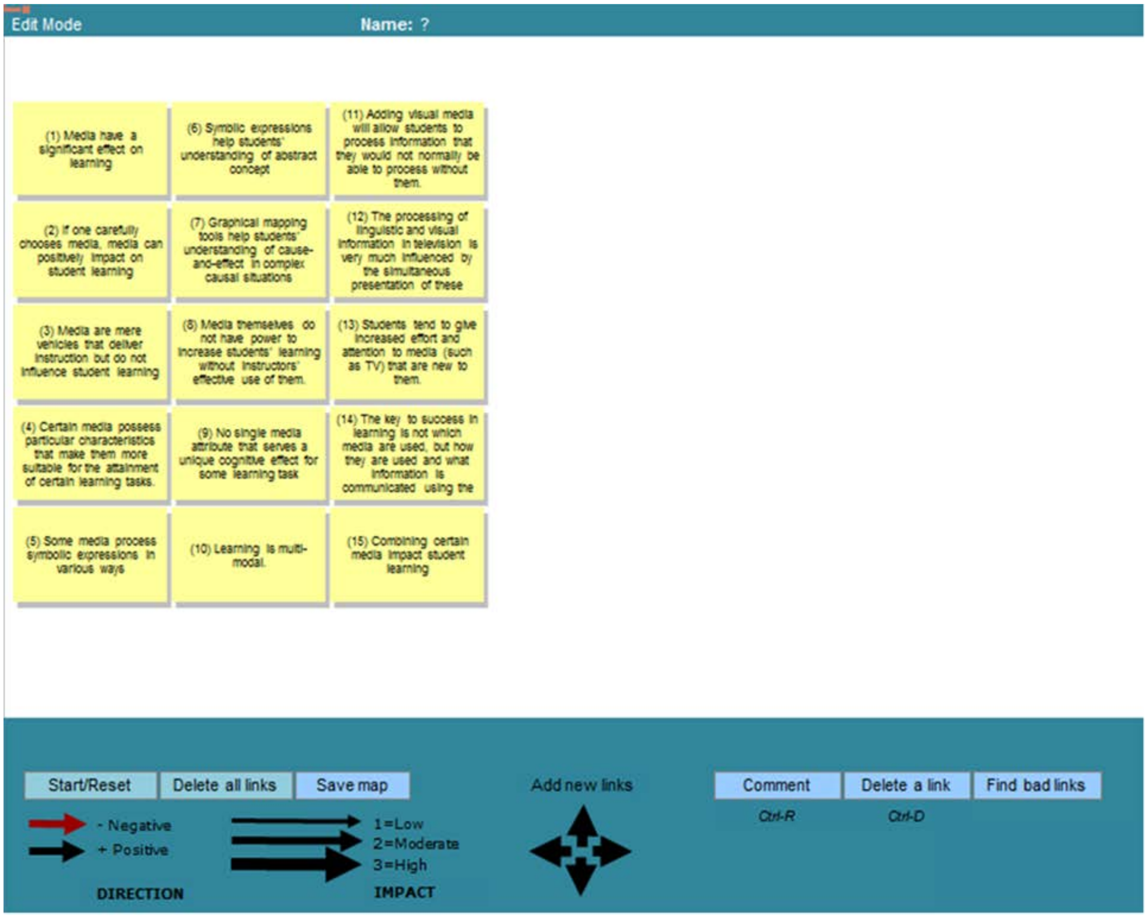
Given that arguments are often complex and ill-structured, argument mapping software have been developed to help students draw diagrams and map out the hierarchical relationships that link minor to major premises (Braak et al., 2006). Diagramming software like Belvedere (De Neys, 2006), Rationale (van Gelder, 2007), and jMAP (Author, 2010) enable students to draw, position, and link multiple nodes to map out, represent, and convey complex hierarchical relationships between premises. Yet, a critical review of the research on argument diagramming and visualizing tools revealed that the majority of the studies found no significant differences (Braak et al., 2006) and were flawed in experimental design. Furthermore, students’ maps often vary widely in accuracy regardless of the instructional intervention (Scavarda, Bouzdine-Chameeva, & Goldstein, 2006). Ruiz-Primo & Shavelson’s (1996) review of the research lead to the conclusion that students' maps should not be used to assess students' learning until students' facility, prior knowledge, and processes used to create the maps are thoroughly examined.

Because no studies at this time have modeled and identified the mapping processes that enable/inhibit students' to accurately analyze/understand complex arguments, Author (2010) recently added to the jMAP software application the ability to chronologically log every action a student performs while constructing an argument diagram within jMAP. This data can be sequentially analyzed to visualize, reveal, and identify the reasoning processes used by each student to produce high and/or low quality argument diagrams. By using this latest version of jMAP, this study addressed the following questions:

1. What sequential patterns in students' argument diagramming processes produce the most versus least accurate argument diagrams?
2. What are the differences in processes used by students that produce the most versus least accurate argument diagrams?

Method

The participants were 17 graduate students enrolled in an online graduate-level course on computer-supported collaborative learning at a large Southeastern university. Students were instructed to review arguments presented in an online debate (taken from another course) to support and oppose the claim: "One's choice of media significantly affects learning". After viewing a short video on how to use jMAP, each student downloaded one jMAP file (which runs in Microsoft Excel 2003+) to diagram the supporting arguments and another jMAP file to diagram the opposing arguments. In both cases, students were presented an initial screen (Figure 1) containing up to 15 nodes (specified in advance by the instructor) representing the main claim, supporting premises, and/or opposing premises. Students were instructed to begin by placing the main claim at the top of the screen.



(1) Media have a significant effect on learning

(2) If one carefully chooses media, media can positively impact on student learning

(3) Media are mere vehicles that deliver instruction but do not influence student learning

(4) Certain media possess particular characteristics that make them more suitable for the attainment of certain learning tasks.

(5) Some media process symbolic expressions in various ways

(6) Symblic expressions help students' understanding of abstract concept

(7) Graphical mapping tools help students' understanding of cause-and-effect in complex causal situations

(8) Media themselves do not have power to increase students' learning without instructors' effective use of them.

(9) No single media attribute that serves a unique cognitive effect for some learning task

(10) Learning is multi-modal.

(11) Adding visual media will allow students to process information that they would not normally be able to process without them.

(12) The processing of linguistic and visual information in television is very much influenced by the simultaneous presentation of these

(13) Students tend to give increased effort and attention to media (such as TV) that are new to them.

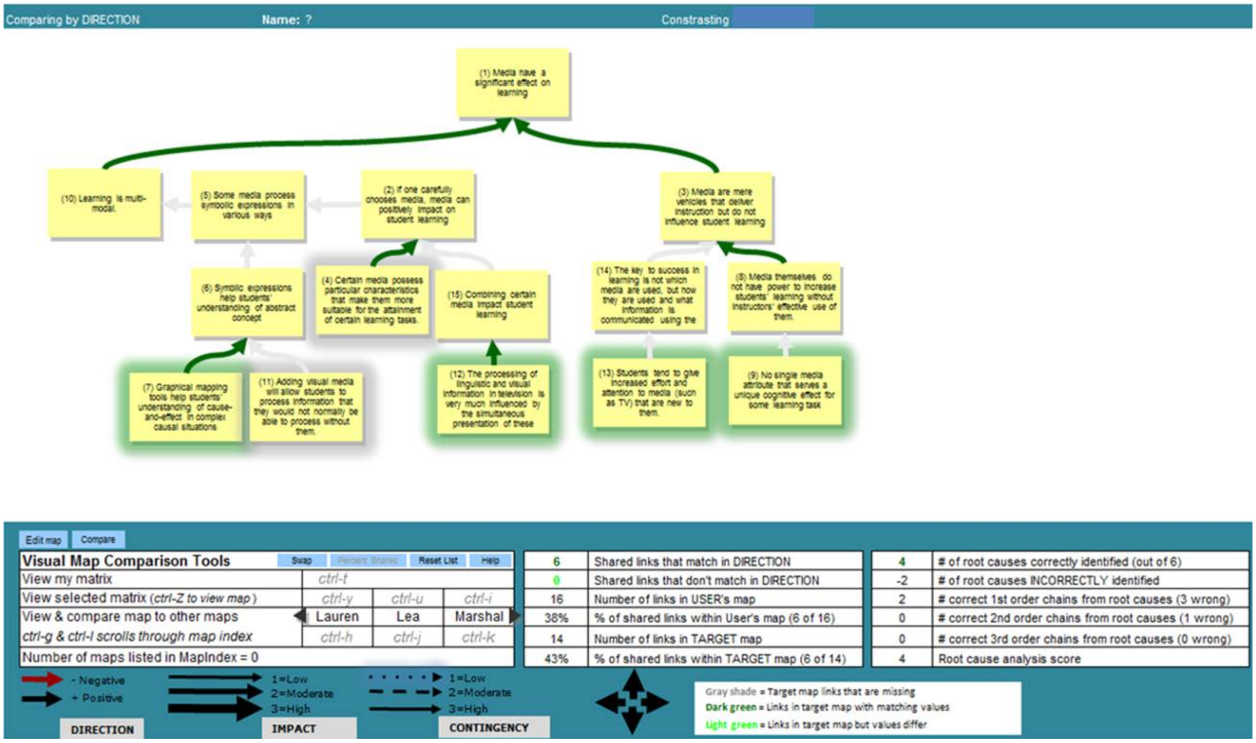
(14) The key to success in learning is not which media are used, but how they are used and what information is communicated using the

(15) Combining certain media impact student learning

Figure 1. Students' initial screen with premises randomly arranged on the screen.

All the students' diagrams were imported into the instructor's jMAP file containing the instructors' argument diagram to score each student's diagram against the instructor's map (Figure 2) across three criteria: a) percentage of links in the student's map that are in the instructor's map; b) number of nodes that were correctly identified as a root premise (node with no arrows pointing inward and at least one arrow pointing outwards); and c) number of correct links stemming directly and progressively from each correctly identified root premise up to the main claim. In figure 3 is the jMAP screen that displays the scores across on each of these criteria (including a weighted cumulative score) for each students' argument diagram. Using the cumulative scores to separate the diagrams with high versus low accuracy, data from the top 6 and bottom 6 diagrams of the *supporting* arguments and from the top 6 and bottom 6 diagrams of the *opposing* arguments were selected to produce a total of 12 best and 12 worst diagrams. The logged actions (Figure 4) recorded in the jMAP files containing the top 12 diagrams were aggregated and then reduced down into six categories to capture more general patterns in students' actions. The same process was repeated with the bottom 12 diagrams.

The data set from the bottom 12 diagrams were imported into the Discussion Analysis Tool (DAT) to produce the frequency, transitional probability, and *z*-score matrices in Figure 5 to reveal sequential patterns in the actions used by students that created the 12 bottom diagrams. The frequency matrix shows for example that when these students added a link, 40 of the 129 actions that immediately followed were also to add a link. To determine if this transitional probability of .31 was significantly higher or lower than the expected probability based on chance alone (and whether AddLink → AddLink can be deemed to be a sequential "pattern"), the *z*-score matrix shows for this particular action-action sequence a *z*-score of 6.55 (which is greater than the critical z-score of ±1.96 at p < .05). As a result, the AddLink → AddLink sequence was found to be a sequential pattern in the actions used by students that produced the bottom 12 diagrams. In all three matrices, the values identified in bold/underline identify action sequences occurring at higher/lower than expected frequency based on the critical *z*-score of ±1.96 at $p < .05$. DAT was then used to convert the reported probabilities into the right transitional state diagram presented in Figure 6. This process was repeated with the data set from the top 12 diagrams to produce the left transitional state diagram in Figure 6 to reveal patterns in the types of action sequences that might in theory help students to produce more accurate argument diagrams.



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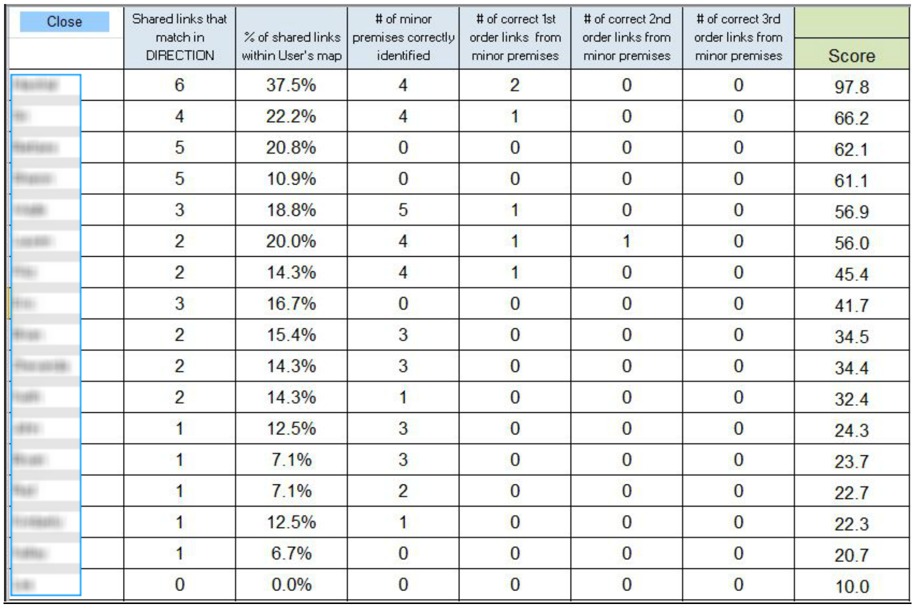
Visual Map Comparison Tools			
View my matrix	ctrl-t		
View selected matrix (*ctrl-Z to view map*)	ctrl-y	ctrl-u	ctrl-i
View & compare map to other maps	Lauren	Lea	Marshal
ctrl-g & ctrl-l scrolls through map index	ctrl-h	ctrl-j	ctrl-k
Number of maps listed in MapIndex = 0			

6	Shared links that match in DIRECTION
0	Shared links that don't match in DIRECTION
16	Number of links in USER's map
38%	% of shared links within User's map (6 of 16)
14	Number of links in TARGET map
43%	% of shared links within TARGET map (6 of 14)

4	# of root causes correctly identified (out of 6)
-2	# of root causes INCORRECTLY identified
2	# correct 1st order chains from root causes (3 wrong)
0	# correct 2nd order chains from root causes (1 wrong)
0	# correct 3rd order chains from root causes (0 wrong)
4	Root cause analysis score

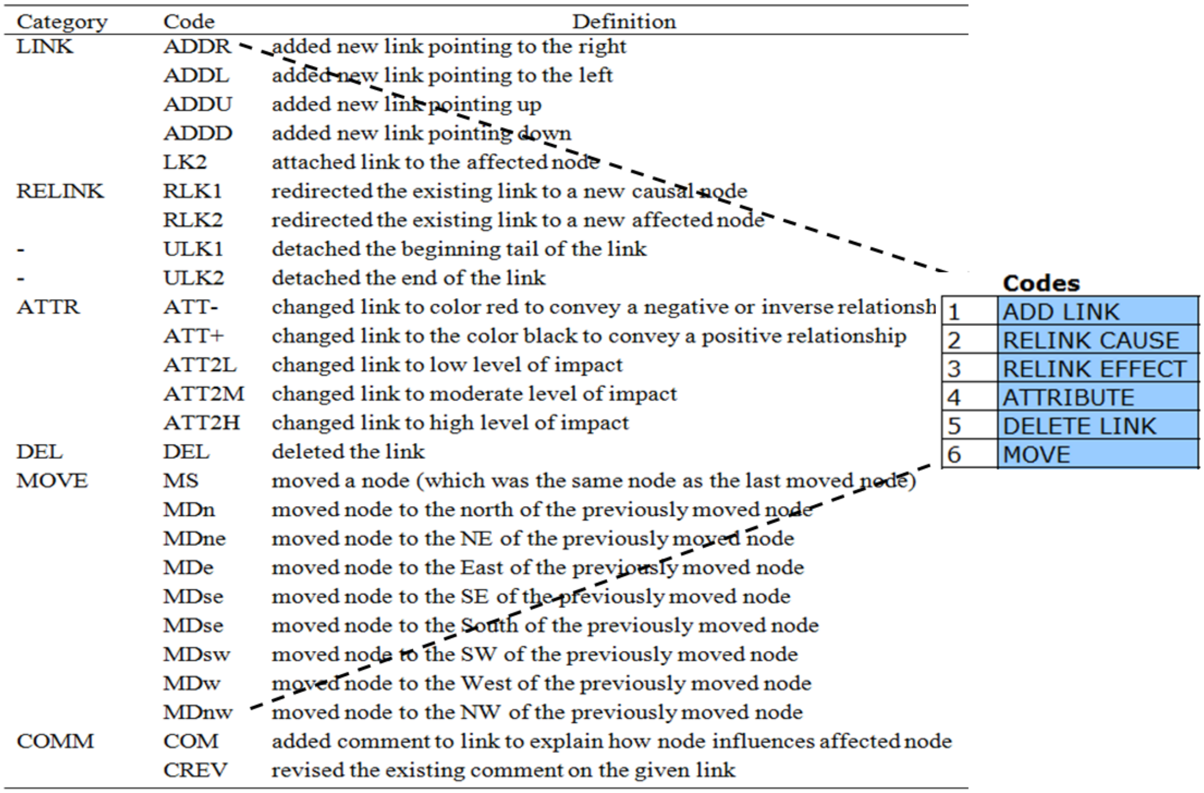
Note: Dark/gray colored arrows identify links present/missing in student x's diagram; Nodes with green halos identify lowest level premises correctly identified by student x.

Figure 2. Instructor's diagram visually and quantitatively compared with student x's diagram.



Close	Shared links that match in DIRECTION	% of shared links within User's map	# of minor premises correctly identified	# of correct 1st order links from minor premises	# of correct 2nd order links from minor premises	# of correct 3rd order links from minor premises	Score
[redacted]	6	37.5%	4	2	0	0	97.8
[redacted]	4	22.2%	4	1	0	0	66.2
[redacted]	5	20.8%	0	0	0	0	62.1
[redacted]	5	10.9%	0	0	0	0	61.1
[redacted]	3	18.8%	5	1	0	0	56.9
[redacted]	2	20.0%	4	1	1	0	56.0
[redacted]	2	14.3%	4	1	0	0	45.4
[redacted]	3	16.7%	0	0	0	0	41.7
[redacted]	2	15.4%	3	0	0	0	34.5
[redacted]	2	14.3%	3	0	0	0	34.4
[redacted]	2	14.3%	1	0	0	0	32.4
[redacted]	1	12.5%	3	0	0	0	24.3
[redacted]	1	7.1%	3	0	0	0	23.7
[redacted]	1	7.1%	2	0	0	0	22.7
[redacted]	1	12.5%	1	0	0	0	22.3
[redacted]	1	6.7%	0	0	0	0	20.7
[redacted]	0	0.0%	0	0	0	0	10.0

Figure 3. Screen shot from jMAP showing scores assigned to students' diagrams of supporting arguments.

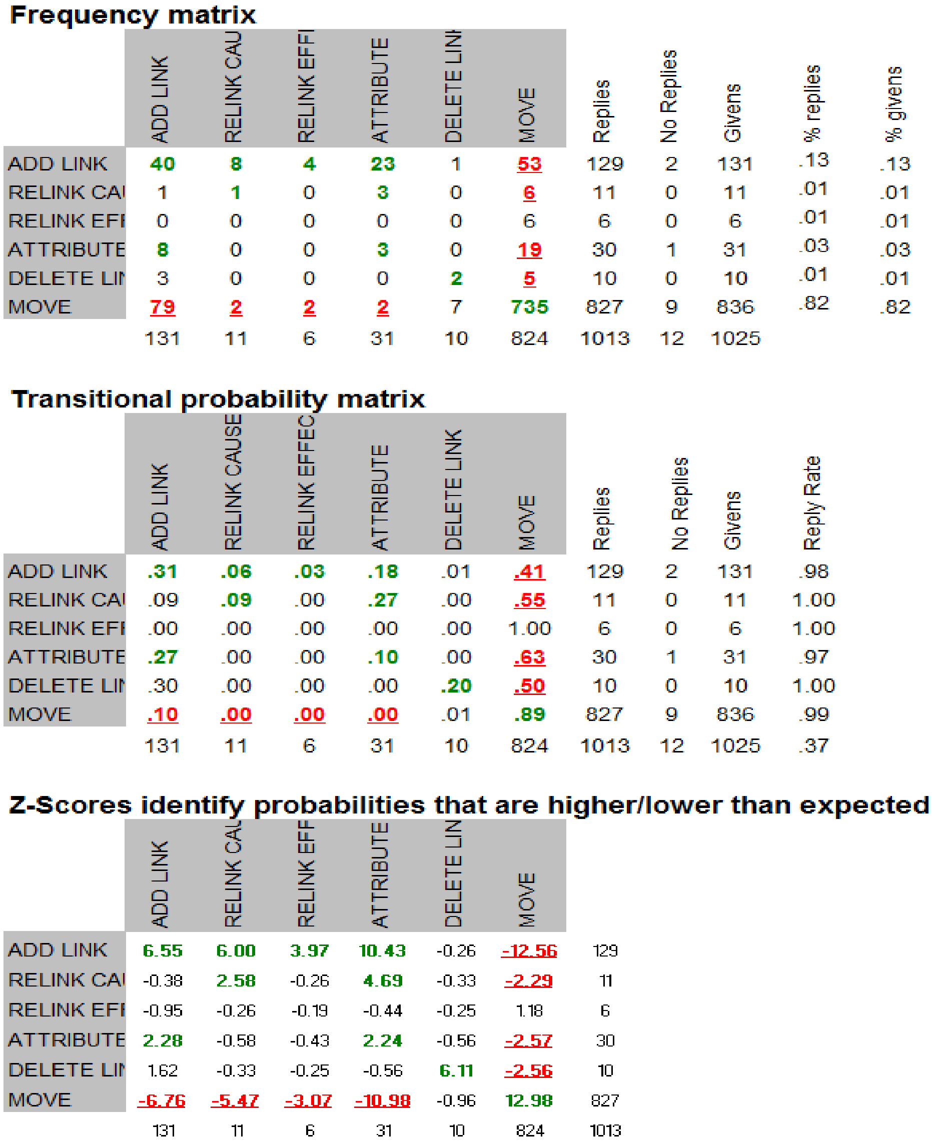


Category	Code	Definition
LINK	ADDR	added new link pointing to the right
	ADDL	added new link pointing to the left
	ADDU	added new link pointing up
	ADDD	added new link pointing down
	LK2	attached link to the affected node
RELINK	RLK1	redirected the existing link to a new causal node
	RLK2	redirected the existing link to a new affected node
-	ULK1	detached the beginning tail of the link
-	ULK2	detached the end of the link
ATTR	ATT-	changed link to color red to convey a negative or inverse relationsh
	ATT+	changed link to the color black to convey a positive relationship
	ATT2L	changed link to low level of impact
	ATT2M	changed link to moderate level of impact
	ATT2H	changed link to high level of impact
DEL	DEL	deleted the link
MOVE	MS	moved a node (which was the same node as the last moved node)
	MDn	moved node to the north of the previously moved node
	MDne	moved node to the NE of the previously moved node
	MDe	moved node to the East of the previously moved node
	MDse	moved node to the SE of the previously moved node
	MDse	moved node to the South of the previously moved node
	MDsw	moved node to the SW of the previously moved node
	MDw	moved node to the West of the previously moved node
	MDnw	moved node to the NW of the previously moved node
COMM	COM	added comment to link to explain how node influences affected node
	CREV	revised the existing comment on the given link

Codes

1	ADD LINK
2	RELINK CAUSE
3	RELINK EFFECT
4	ATTRIBUTE
5	DELETE LINK
6	MOVE

Figure 4. Codes assigned to each action students perform in jMAP while constructing an argument diagram.



Frequency matrix

	ADD LINK	RELINK CAU	RELINK EFFI	ATTRIBUTE	DELETE LIN	MOVE	Replies	No Replies	Givens	% replies	% givens
ADD LINK	40	8	4	23	1	53	129	2	131	.13	.13
RELINK CAI	1	1	0	3	0	6	11	0	11	.01	.01
RELINK EFI	0	0	0	0	0	6	6	0	6	.01	.01
ATTRIBUTE	8	0	0	3	0	19	30	1	31	.03	.03
DELETE LII	3	0	0	0	2	5	10	0	10	.01	.01
MOVE	79	2	2	2	7	735	827	9	836	.82	.82
	131	11	6	31	10	824	1013	12	1025		

Transitional probability matrix

	ADD LINK	RELINK CAUSE	RELINK EFFEC	ATTRIBUTE	DELETE LINK	MOVE	Replies	No Replies	Givens	Reply Rate
ADD LINK	.31	.06	.03	.18	.01	.41	129	2	131	.98
RELINK CAI	.09	.09	.00	.27	.00	.55	11	0	11	1.00
RELINK EFI	.00	.00	.00	.00	.00	1.00	6	0	6	1.00
ATTRIBUTE	.27	.00	.00	.10	.00	.63	30	1	31	.97
DELETE LII	.30	.00	.00	.00	.20	.50	10	0	10	1.00
MOVE	.10	.00	.00	.00	.01	.89	827	9	836	.99
	131	11	6	31	10	824	1013	12	1025	.37

Z-Scores identify probabilities that are higher/lower than expected

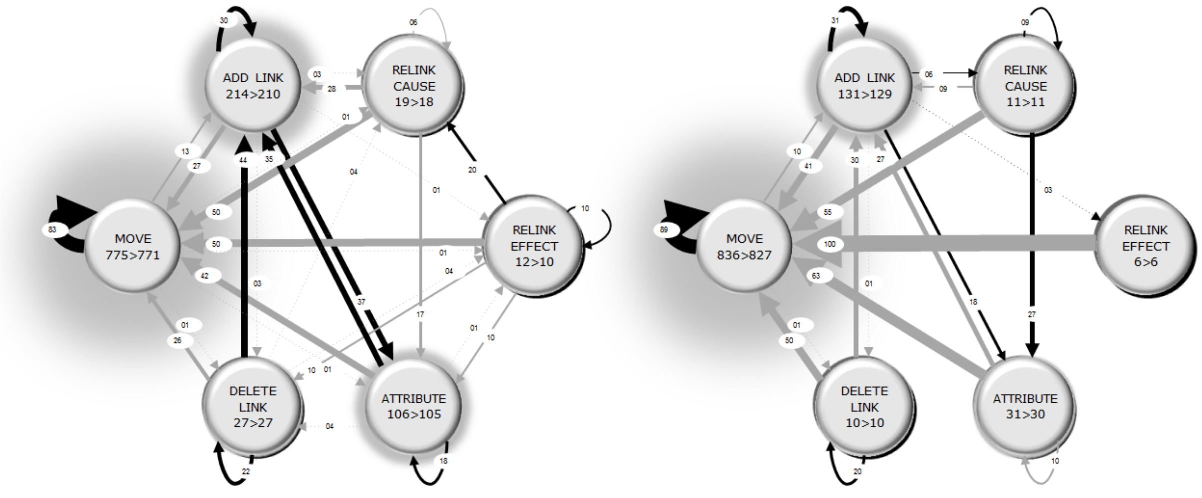
	ADD LINK	RELINK CAU	RELINK EFF	ATTRIBUTE	DELETE LIN	MOVE	
ADD LINK	6.55	6.00	3.97	10.43	-0.26	-12.56	129
RELINK CAI	-0.38	2.58	-0.26	4.69	-0.33	-2.29	11
RELINK EFI	-0.95	-0.26	-0.19	-0.44	-0.25	1.18	6
ATTRIBUTE	2.28	-0.58	-0.43	2.24	-0.56	-2.57	30
DELETE LII	1.62	-0.33	-0.25	-0.56	6.11	-2.56	10
MOVE	-6.76	-5.47	-3.07	-10.98	-0.96	12.98	827
	131	11	6	31	10	824	1013

Figure 5. Screen shot from DAT showing the frequency, transitional probability, and *z*-score matrices used to reveal sequential patterns in the actions used to create the 12 bottom diagrams.

Main Findings

The two state diagrams in Figure 6 reveal four action-action sequences that were common in both groups (AddLink→AddLink, MoveNode → MoveNode, and DeleteLink → DeleteLink, AddLink → ChangeLinkAttribute). The first three action sequences suggest for example that students constructed their diagrams using a stage-like sequence by moving multiple premises into position first, then inserting links to connect the premises with links, and then deleting (or correcting) the links between premises. Given that these four processes were observed in both groups, the findings suggest that the use of these four processes neither increases nor decreases the accuracy of students' argument diagrams.

The state diagrams also shows that top scorers exhibited five unique patterns in action sequences – patterns exhibited only among the higher performers. For example, the left state diagram shows that when top scorers deleted a link, they were most likely (44%) to follow that action by adding a new link between nodes than bottom scorers. When they specified the attribute of the link, they were most likely (35%) to follow that action by adding a new link. Overall, the differences between the two state diagrams suggest that the following five action sequences (when performed on a more consistent basis) can help students construct more accurate diagrams: DeleteLink→AddLink, Attribute→AddLink, Attribute→Attribute, Relink Effect (move the head of the arrow to point to another affected node)→Relink Effect, and Relink Effect→Relink Cause (move tail of arrow to point to another causal node). In particular, the sequence of DeleteLink → AddLink may be an indication of times when students are restructuring their diagrams to undo an error produced when making hasty generalizations (when A→Conclusion and B→Conclusion should in fact be restructured to A→B→Conclusion).



Top 12 Diagrams

Bottom 12 Diagrams

Note: Thickness of arrow conveys strength of transitional probability; dark black arrows identify probabilities that are significantly greater than expected based on *z*-score tests ($p < .01$) performed in the DAT software; first and second numerical value displayed in nodes identify the number of times the given action was performed and the number of events that followed the given action; the size of the glow emanating from each node conveys the number of times the action was performed.

Figure 6. State diagrams of processes used to produce the top 12 vs. bottom 12 diagrams.

In contrast, the low performing students exhibited four patterns in action sequences that were not observed among the high performing students – action sequences that when performed on a more consistent or more frequent basis can potentially lead students to produce less accurate argument diagrams. These four patterns were AddLink → RelinkCause (change tail of link to point to a supporting or subordinate premise), AddLink → RelinkEffect (change head of link to point to a superordinate premise), Relink Cause → Relink Cause, and Relink Cause → ChangeLinkAttribute. Given that the low performing students exhibited the tendency to perform the RelinkCause → RelinkCause sequence whereas the high performing students exhibited the tendency to perform the RelinkEffect → RelinkEffect sequence, these differences might serve to indicate that the processes used to: a) create the more accurate argument diagrams involved to some extent the use of a forward or bottom up approach - systematically examining which major premise (or effect) is supported by a given minor premise (or effect); and b) create the less accurate diagrams involved the use of a backward or top-down approach by progressively examining which minor premise supports a given major or superordinate premise.

Conclusions and Implications

Although the findings in this study are only preliminary and hence are not conclusive, the observed differences in the action sequences used by students that constructed argument diagrams of high versus low accuracy provide initial insights into the types of action sequences that can be promoted/encouraged to help students create more accurate diagrams and to achieve deeper understanding of complex arguments. At minimum, the findings and the possible interpretations of the meaning behind the findings provides some insights into the possible methods and approaches that can be used in future research to model and better understand the processes that can be used effectively to analyze and better understand complex arguments.

Future work will be necessary to: a) replicate this study with a larger sample size; b) test different approaches to establishing the validity of the criterion used to assess the accuracy of students' argument diagrams, c) refine the precision of the data mining codes in jMAP to fully determine if students are in fact linking premises using a forward or backward approach and are sequentially relinking premises into logical chains to correct for errors produced by making hasty generalizations; d) identify which diagramming actions are and are not capable of capturing general reasoning processes that improve argument analysis (areas B and E in Figure 7, respectively); e) integrate the target action sequences directly into the software interface of the argument diagramming software so that controlled experiments can be conducted to determine the cause-effect relationship between target processes and map accuracy; f) determine to what extent particular processes are and are not dependent on students' prior knowledge in order to identify the target processes that can be promoted regardless of students' prior knowledge; and f) examine to what extent the target processes are effective across different arguments of varying complexity in hierarchical structure.

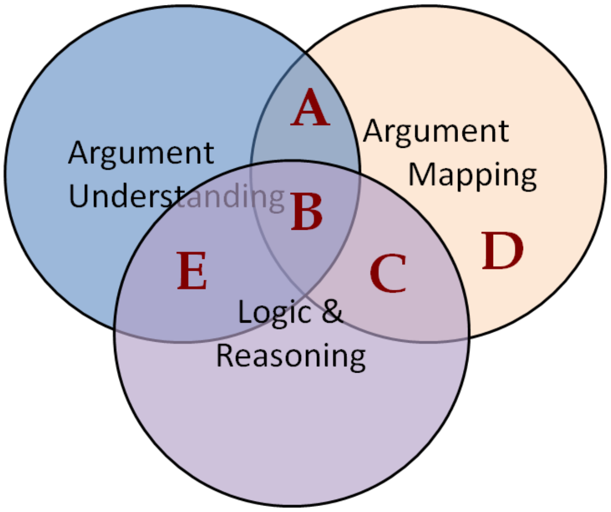


Figure 7. Areas for further research on the relationships between diagramming processes, general reasoning processes, and understanding of complex arguments.

References

Braak, S. W. van den., Oostendorp, H. van., Prakken, H., & Vreeswijk, G. A. (2006). A critical review of argument visualization tools: Do users become better reasoners? In F. Grasso, R. Kibble, & C. A. Reed (Eds.), *Workshop Notes of the ECAI-2006 Workshop on Computational Models of Natural Argument* (pp. 67-75). Riva del Garda:Italy.

De Neys, W. (2006). Dual processing in reasoning two systems but one reasoner. *Psychological Science*, *17*(5), 428-433.

Kuhn, D. (1991). *The Skills of Argument*. Cambridge: Cambridge University Press.

McLean, Cheryl (2005). Evaluating critical thinking skills: Two conceptualizations. *Journal of Distance Education*, *20*(2), 1-20.

Paul, R., & Elder, L. (2001). *The Miniature Guide to Critical Thinking: Concepts & Tools*. Dillon Beach, CA: The Foundation for Critical Thinking.

Ruiz-Primo, M., & Shavelson, R. (1996). Problems and issues in the use of concept maps in science assessment. *Journal of Research in Science Teaching*, *33*(6), 569-600.Scavarda et (2006).

Scavarda, A.J., Bouzdine-Chameeva, T., Goldstein, S.M., Hays, J.M., & Hill, A. V. (2006). A methodology for constructing collective causal maps. *Decision Sciences Journal*, *37*(2), 263-284.

van Gelder, T. J. (2007). The rationale for Rationale™. *Law, Probability and Risk*, *6*, 23-42. doi:10.1093/lpr/mgm032.