Social Regulation of Epistemic Thinking During Collaborative Inquiry with Multiple Documents

Supplementary Material

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Table S1

Bighorn Sheep Unit Document Characteristics

#	Title	Source Byline	Publication Type	Main Claim	Evidence
1	Meet the Bighorn Sheep	Published on the National Geographic website on 25 October 2000	Popular science website article	Some argue that the Bighorn sheep have changed, and others say that they have not changed.	NA
2	Bighorn Sheep: Preserving a Valuable Resource	By Jayne Moore. Newspaper article in the Alberta Sentinel, a newspaper in Canada, published on June 5th, 2008	General newspaper article	There have been no changes in the size of the horns of the sheep.	Testimonies of four hunters and hikers.
3	Changes in North American Bighorn Sheep Over the Last 25 Years	By Dr. Coltman, Dr. O'Donoghue, & Dr. Jorgenson, published in February 2012 in the scientific journal Nature. Drs. Coltman, O'Donoghue, and Jorgenson are biologists from a university in Canada.	Scientific journal article	The horn size of male bighorn sheep has decreased over the last 25 years.	Systematic study of horn size over 25 years.
4	Wildlife Forum	Messages posted on the Big Hunters Forum on 17.6.2013	Discussion on an Internet forum	The bighorn sheep population is declining because of Pneumonia.	Rumors on an online forum.
5	The Impact of Trophy Hunting on Bighorn Sheep	By Dr. Heller, published in September 2010, in the scientific journal Ecological Trends. Dr. Heller is a biologist from a university in Canada.	Scientific journal article	Sheep that hunters kill have significantly bigger horns on average compared to sheep that die from other causes.	Systematic analysis of hunting records and of Bighorn mortality reports.
6	The Causes of Bighorn Sheep Mortality	A Report Published by the Alberta Parks and Wildlife	Report by a professional	Hunting is the main cause of death for male	Radio collar tracking of a sample of

#	Title	Source Byline	Publication Type	Main Claim	Evidence
		authority on September 2015.	public organization	sheep and vehicle collisions is the main cause of death for female sheep.	Bighorn sheep and investigation of death causes.
7	Hereditary Traits in Bighorn Sheep	By Dr. King & Dr. Howard, published in April 2008 in the scientific journal Biological Science. Dr. King & Dr. Howard are biologists from a university in the United States.	Scientific journal article	Horn size is a hereditary trait among bighorn sheep. Older males have more offspring than younger males.	Radio collar tracking of a sample of Bighorn sheep, horn size measurement, and DNA tests for all rams and lambs.
8	Bighorn Sheep Hunting Adventures	Published on the Alberta Wild Sheep Hunting company website on April 2016	Commercial website of a professional company	Hunting does not cause a decrease in horn size because the remaining sheep produce offspring with big horns.	Testimony of professional hunters.
9	Sometimes It Is Better to Be Older	Excerpt from an article published by Hanna Alvarez in Popular Science, a popular science magazine, in 2015	Popular science magazine article	Older males have more offspring than younger males.	Radio collar tracking and observations over twenty years.

Table S2

Inquiry Session Protocol

Phase	Instructions and prompts
Introduction	"Today we are going to start working on the [e.g., HIV] task. As you know [e.g., HIV is a dangerous disease, and scientists are making great efforts to find ways to prevent and cure this disease]. This question is a real scientific mystery that scientists have been investigating in recent years."
Presentation of inquiry prompt	"In the session today, I would like you to focus on a specific question that will help you in your investigation. The question is: [e.g., Is there resistance to HIV?]." (Place printed page with question on the table).
Providing documents	In the first session of the unit: "Here are three pieces[1] about the topic of [e.g., HIV immunity]. These pieces are pieces about the topic that we found on the Internet. Your goal is to read these pieces and to find out [e.g., if there is resistance to HIV]". (Place the three printed documents on the table). In the second and third sessions of the unit: "In the previous meeting/s you read three/six pieces and came to the conclusion that [briefly state students' conclusion from the last session]. The pieces from last time are here, in case you want to look at them again. In this session, I am going to ask you to read another three pieces on this topic to try to find out [inquiry prompt]". (Place the three new documents in the middle of the table and put the documents from the last session/s of this unit on the side of the table).
Collaborative reading of each document	"As you know, this is a collaborative activity. I would like you to work on this activity together, to talk to each other, and to solve this problem together. Please read the pieces together. Read them one by one. You can read them in whichever order you like. As you read each piece, please discuss between yourselves what you can find out from this piece regarding [inquiry prompt]. You can speak freely and say everything you think and whatever comes to your mind when you read this piece. After you finish discussing between yourselves, tell me what you found out from this piece regarding [the inquiry question]."
Drawing conclusions from each document	After students finish discussing each piece, ask: • "Have you finished discussing this piece?" • If yes: "So, what have you found out about [the inquiry question] based on this piece?" • "Is there anything else? / Do you have anything else to add?"
Drawing conclusions from all documents	After students finish reading and discussing all articles, say: "Now, please talk among yourselves and decide what your conclusion is regarding [the inquiry question] based on all of the pieces that you have read so far, including pieces from previous sessions. When you reach a conclusion, let me know."

[1] We used the term *piece* to refer to the documents throughout the study. We preferred this everyday term over the more technical terms of *document* and *information source*.

Phase	Instructions and prompts

	After students finish discussing, ask:
	• "According to these pieces, including all the pieces that you read up until now, [restate the inquiry question, e.g. is there resistance to HIV]?"
	• "Please explain why you think that [restate their conclusion]?
	  o "Why else?" / "Is there another reason why you think this way?"
	• "How do you know that?"
	  o "How else do you know it?"
	• "To what degree are you certain about your conclusion?"
	  o "Why?"
	• "Do you both think exactly the same about this question?"
	  o If they disagree: "What do you disagree about?"
	  o If they disagree: "Why do/did you disagree?"

Note: Comments in square brackets were adapted to specific units and sessions.

Table S3

Epistemic Aims Coding Scheme

Codes	Definitions	Examples
Answering the inquiry question	Students mention or describe the goal of arriving at an answer to the inquiry question or reaching a conclusion.	"We succeeded in answering the question."
Understanding task instructions	Students mention or describe the goal of understanding the expected task outcomes or of understanding what the question is and how it applies to the task.	"When they say how did hunting cause a change in the horns of the sheep? They mean a change in size?"
Understanding the documents or topic	Students mention or describe the goal of understanding the documents' content or the phenomena of interest.	"So how do they know if the monkeys are resistant or non-resistant? Do you understand?"
Providing justification	Students mention or describe that their goal is to justify or explain their conclusion regarding the inquiry question.	"I have to prove now that it happens at all. Ahh..."

Table S4

Epistemic Ideals Coding Scheme

Codes	Definitions	Examples
Ideals for Evaluating Document Sources and Contents		
Document relevance	Students refer to the relevance of the document or the content to the topic or inquiry question.	"It's unrelated to our question."
Source trustworthiness	Students refer to the credibility of the sources of the information, including the authors, informants mentioned in the documents, publication types, publication venues, and publication time. They may mention general trustworthiness or specific attributes such as expertise, benevolence, recency, etc.	"It was in a really unprofessional forum."
Evidence reliability and quality	Students refer to the reliability, quality, or consistency of the empirical data and the research methods that were presented in the documents.	"I don't like that they say it's 'very big'. I need the size [of the horns]."
Acknowledging research limitations	Students explicitly refer to the limitations of the research methods described in the documents, including sampling limitations, methodological uncertainty, errors, topic complexity, and more.	"But the piece speaks about domestic cats [rather than humans]."
Truth or correctness	Students refer to the truth or correctness of the claims, information, or conclusions. Students may discuss why some things are considered correct or not.	"This may be, it gives us the truth."
Ideals for Evaluating Own Conclusions		
Reliability of the conclusion	Students refer to the reliability or trustworthiness of their own answer or conclusion.	"We can say that toads caused this change, it's like the best thing we have. The most reliable**.**"
Certainty of the conclusion	Students refer to the certainty of their answer or conclusion or state their level of certainty regarding the conclusion.	"[I'm] not sure if it is genetic or not. Because it's still not really quite clear."
Evidentiary support sufficiency	Students mention if their answer or conclusion is supported by enough empirical evidence. They may also state that the answer or conclusion should be based on sufficient evidence or that it is not possible to draw a conclusion because the evidence is inadequate.	"He showed a picture. So what? There are a lot [of sheep]. It can be a one incident. You can't know."

Table S5

Document Evaluation and Comprehension Processes Coding Scheme

Code	Definition	Examples
Content elaboration or inferencing	Students explain the content of the document or elaborate it, going beyond what is stated. Students make inferences from the content.	"Resistance is a recessive trait. It means she's like... It's a small a. I won't go into that. In short, if there is a parent who is not resistant, he will always triumph over the resistant parent."
Content understanding efforts	Students try to understand the content of the doc by asking questions or discussing hard-to-understand parts.	"What is intestinal inflammation?"
Evidence evaluation	Students evaluate the quality, reliability, or accuracy of the data or the methods used to obtain data.	"They didn't show us two pictures from 50 years ago and later. That document relies on opinion."
Source evaluation	Students evaluate the trustworthiness of the sources. Students may also evaluate the content in light of source attributes.	"Yes. We learned nothing from document #4 because it was posted long ago and in a forum by just a guy [nickname in forum]."
Cross-textual linking: Identifying similarities	Students compare the documents and identify similarities or overlaps in information, conclusions, or evidence.	"They say the same thing here as in piece #6."
Cross-textual linking: Identifying differences	Students compare the documents and identify inconsistencies or conflicts in information, conclusions, or evidence.	"Here, actually, it means the opposite. The snake has lengthened, but its head is smaller...".
Cross-textual linking: Identifying complementary relations	Students compare the documents and identify that one document adds information that complements, explains, or supports the information in another document.	"Piece #5 and piece #2 both kind of support #6, because the immune system of humans and animals is not so different."

Table S6

Conclusion Construction Processes Coding Scheme

Codes	Definitions	Examples
Concluding a single document	Students propose a conclusion or an answer to the inquiry question based on a specific document.	"So is there resistance? It may be so because according to this piece, you can see that in monkeys, they can be resistant and it passes in genes."
Drawing a conclusion from multiple documents	Students propose a conclusion or an answer to the inquiry question based on at least two documents.	"It is the toads, and it is mostly related to genes [Document #6]. Like, not genes. What is it called? Offspring. It's the offspring [Document #5]. Because the toads actually kill the snakes with a shorter body and a larger head, and leave only the snakes with the small heads and the long body [Document #9]. Actually, these have more chances of surviving […] So, we think toads caused it."
Novel hypothesis or explanation	Students raise a novel hypothesis, conjecture, or explanation that does not appear in the documents and that cannot be inferred solely from them.	"There is a chance that it is the climate because the climate really affects the animals. So, a hole in the ozone in fact exists today. It could be the ozone hole. " [Climate change and the ozone hole were not mentioned in the documents.]
Justification based on a single document	Students explain or support their conclusion by mentioning claims, information, evidence from one document or by noting a document number.	"We think there is external resistance because we read piece #4, which gave the thought that there are foods or external factors."
Justification based on multiple documents (w/o corroboration or integration)	Students explain or support their conclusion by mentioning claims, information, or evidence from at least two documents or by noting document numbers. They do <u>not</u> explicitly corroborate or integrate information across the documents.	"[How do you know that?] Mainly according to the last documents."
Justification based on corroboration or integration of multiple documents	Students explain or support their conclusion by mentioning claims, information, or evidence from at least two documents or by noting document numbers. They explicitly corroborate or integrate information across the documents.	"According to documents #2 and #5, it helped us because we know that the immune systems are not too different if we are talking about similar diseases. Then we continued to document #6 that explained to us that someone was resistant, although they did not explain why he was resistant."

Codes	Definitions	Examples
Justification based on evidence quality or reliability	Students explain or support their conclusion by referring to evidence features such as the quality and adequacy of the research methods or samples.	"Because in piece #4 it was really serious [research]. It was, like, how many was it? How many participated? A lot."
Justification based on document or source trustworthiness	Students explain or support their conclusion by referring to source credibility, such as general reliability, expertise, motivations, etc.	"We discovered that genetic resistance is not for all strains of HIV, according to piece #9. That is the only piece that we believe in."
Justification based on explanation of a biological mechanism	Students explain or support their conclusion by describing or explaining a biological mechanism that was inferred from the documents.	"If people are resistant, they do not have the CCR5 [receptor]. But five percent of HIV strains can still hurt them; it means that they enter [the cell] another way and not through the CCR5."

Table S7

Mean Frequencies and Proportions of Metacognitive Regulation Modes by AIR Component in Each Unit in Both Dyads

Regulation Modes	AIR Components	Unit 1 - Dyads 6 & 12		Unit 2 - Dyads 6 & 12		Unit 3 - Dyads 6 & 12		Unit 4 - Dyads 6 & 12	
		f	**%**		**%**	***f***	**%**	***f***	**%**
Self-Regulation	Aims	8.5	35.4	3.5	14.9	5.5	24.4	6.0	26.1
	Ideals	9.5	19.8	12.5	27.5	14.5	26.9	9.5	25.7
	Processes	21.0	20.6	20.0	19.0	19.5	18.0	21.5	21.6
	All components	**39.0**	**22.4**	**36.0**	**20.6**	**39.5**	**21.4**	**37.0**	**23.2**
Co-Regulation	Aims	0.5	2.1	4.0	17.0	2.5	11.1	3.5	15.2
	Ideals	0.5	1.0	5.5	12.1	5.5	10.2	3.0	8.1
	Processes	11	10.8	10.5	10.0	15.5	14.3	15.5	15.6
	All components	**12.0**	**6.9**	**20.0**	**11.5**	**23.5**	**12.7**	**22.0**	**13.8**
Shared Regulation	Aims	12	50.0	11.5	48.9	11.0	48.9	12.0	52.2
	Ideals	9	18.8	11.5	25.3	19.0	35.2	15.0	40.5
	Processes	25	24.5	25.5	24.2	25.5	23.5	24.0	24.1
	All components	**46.0**	**26.4**	**48.5**	**27.8**	**55.5**	**30.0**	**51.0**	**32.0**

Note. *f* = Mean number of AIR component occurrences that were regulated at least once in both dyads in each mode; % = Mean proportion of regulated AIR components out of the total component occurrences in each unit in both dyads.

Table S8

Mean Frequencies and Proportions of Metacognitive Regulation Skills by AIR Component in Each Unit in Both Dyads

Metacognitive Regulation Skills	AIR Components	Unit 1 - Dyads 6 & 12		Unit 2 - Dyads 6 & 12		Unit 3 - Dyads 6 & 12		Unit 4 - Dyads 6 & 12	
		f	%	*f*	%	*f*	%	*f*	%
Metacognitive Monitoring	Aims	13.0	54.2	14.0	59.6	12.0	53.3	15.5	67.4
	Ideals	13.5	28.1	24.0	52.7	30.0	55.6	19.0	51.4
	Processes	36.0	35.3	37.5	35.5	42.5	39.2	40.5	40.7
	All components	**62.5**	**35.9**	**75.5**	**43.3**	**84.5**	**45.7**	**75.0**	**47.0**
Metacognitive Planning	Aims	7.0	29.2	4.0	17.0	6.5	28.9	5.5	23.9
	Ideals	2.5	5.2	1.5	3.3	4.0	7.4	1.5	4.1
	Processes	9.5	9.3	8.0	7.6	6.0	5.5	7.0	7.0
	All components	**19.0**	**10.9**	**13.5**	**7.7**	**16.5**	**8.9**	**14.0**	**8.8**
Metacognitive Controlling	Aims	0.5	2.1	0.0	0.0	0.0	0.0	0.0	0.0
	Ideals	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Processes	2.0	2.0	3.0	2.8	5.0	4.6	3.0	3.0
	All components	**2.5**	**1.4**	**3.0**	**1.7**	**5.0**	**2.7**	**3.0**	**1.9**
Metacognitive Evaluating	Aims	0.5	2.1	0.5	2.1	0.5	2.2	0.5	2.2
	Ideals	0.0	0.0	0.5	1.1	0.0	0.0	0.0	0.0
	Processes	1.0	1.0	2.0	1.9	4.0	3.7	1.5	1.5
	All components	**1.5**	**0.9**	**3.0**	**1.7**	**4.5**	**2.4**	**2.0**	**1.3**

Note. *f* = Mean number of AIR component occurrences that were regulated at least once in both dyads in each regulation skill; % = Mean proportion of regulated AIR components out of the total component occurrences in each unit in both dyads.