Understanding Working Memory through Argumentation

Dr. Ozden Sengul
Bogazici University, Turkey

Abstract

Next Generation Science Standards suggest that teachers should address scientific practices, disciplinary core ideas, and crosscutting concepts to enhance students` understanding of how science works. This paper illustrates how five pre-service mathematics teachers' use of argumentation can be promoted in a life science lesson to teach the memory and stimuli concept. Pre-service teachers collected data from 50 adults (25 men, 25 women) by using the memory cards including letters and numbers in different complexity. The student teachers recorded how many numbers and/or letters were remembered by each adult. The data were analyzed using descriptive statistics. The pre-service teachers found that as the complexity of information on the cards increased, adults had difficulty remembering; information processing became difficult. The article includes suggestions about how to integrate the argumentation to enhance teachers and students' ability to collect and interpret the data while answering scientific research questions.

Keyword: argumentation, instructional strategies, teaching and learning science

Next Generation Science Standards guides science teachers to integrate science and engineering practices, crosscutting concepts, and disciplinary core ideas (NGSS Lead States, 2013). In recent years, different instructional models have been developed to integrate laboratory investigations to address the suggestions of science standards. These instructional models help to develop an organized logical plan for instructional activities to incorporate cognitive, social, and epistemic aspects of science into science teaching rather than traditional, teacher-centered instruction (Duschl, 2008). For example, as a research-based instructional model, Argument-Driven Inquiry (ADI) promotes students' understanding of the science content and scientific thinking through the design of an investigation, data collection and analysis, exchanging ideas, discussing findings with peers, and constructing evidence-based explanations (Sengul, 2018). Research on the implementation of the ADI model shows that the model provides a great promise and potential to improve students` literacy skills such as reading, speaking, and writing along with conceptual understanding. During the ADI investigations, students work in small groups to design a method for data collection and analysis with the appropriate materials and develop an argument including a claim, evidence, and justification of evidence. The claim is an answer for the research question, the evidence is the interpretation of data collected through measurements and observations in the form of numerical or graphical representations, and justification of evidence explains how the scientific principles support the relationship between evidence and claim. However, science teachers may interpret and enact the ADI model differently to maximize diverse students` learning (Sampson et al., 2013). While some teachers use the instructional sequences verbatim or with strict fidelity, the others change, modify, or combine the sequences based on various factors such as beliefs, student ability, or context (Sengul et al., 2021).

The ADI instructional model includes the following steps (Argument-Driven Inquiry, n.d.): 1) *Task* phase introduces a phenomenon, task, or problem. 2) *Ideas* phase encourages students to share their ideas about the investigation. 3) *Plan* phase guides students to plan a method for data collection and analysis. 4) *Do* phase helps students to collect and analyze data. 5) *Share* phase provides an opportunity to construct, critique, and revise evidence-based explanation. 6) *Reflect* phase emphasizes promoting discussion about how to address science content and practices. 7) *Report* phase is based on how students write, share, critique, and revise investigation reports.

To illustrate how a teacher modifies the ADI instructional model, this paper describes a laboratory-based instruction on a life science topic. This lesson is designed by five pre-service mathematics teachers to help learners understand information processing as a core idea to explain how people use their memory to respond to stimuli. During the study, pre-service teachers had the memory cards to collect data. Five student teachers collected data from 50 adults (25 men, 25 women) and analyzed the results using descriptive statistics. The design of the lesson and the results presented below:

The lesson task

In this lesson, the teacher aims to integrate both high school and middle school science standards in the lesson (NGSS Lead States, 2013):

HS-LS1-2: Develop and use a model to illustrate the hierarchical organization of interacting systems that provide specific functions within multicellular organisms.

MS-LS1-8: Gather and synthesize information that sensory receptors respond to stimuli by sending messages to the brain for immediate behavior or storage as memories.

The lesson also engages students in scientific practices including carrying out a scientific experiment by collecting and analyzing the empirical data, and obtaining, evaluating, and communicating information. They also understand cause and effect relationships in a system: how scientists study the system's structure and how the structure of the brain influences the way it functions. The implementation of original ADI investigations takes more than five hours, and science teachers may need to modify the instructional sequences for shorter lessons (Sengul et al., 2020). This lesson exemplifies how to modify the ADI model from seven stages to three stages and address the important elements of the science standards in a two-hour life science lesson in a high school classroom including higher and lower achieving students.

Introducing the task- TASK (20 minutes). At the beginning, the teacher aims to capture students` attention and elicit their prior understandings through introducing the topic and offering a guiding question to investigate. The aim of this activity is to explore how the amount of information and the order in which it is presented affects what people can remember. The guiding question of this investigation is, **how does the way information is presented affect working memory?** (Enderle et al., 2015).

Figure 1
Introductory paragraph on the topic: Memory and Stimuli

Memory and Stimuli (Enderle et al., 2015)

The brain gets information about the world around the body through *senses* (hearing, seeing, tasting, smelling, and touching). Our senses take in information about the stimuli and send it to the brain by chemical and electrical signals. The brain reads that information and acts on it in several ways: *Short-term memory* keeps information for only a few seconds. *Working memory* keeps information for just a little longer, allowing us to organize it and make sense of it. *Long-term memory* keeps lots of information for long periods of times. The brain is able to take in more information faster and retain it longer if the information is presented in a pattern, which can make it easier for our brains to make sense of the world. The problem: How does the way information is presented affect working memory?

Your task is to plan and carry out an investigation to answer this question through collecting and analyzing data and providing an evidence-based explanation.

Materials: Set of cards including numbers and letters, timer

The teacher provides a paragraph to read about a problem (Figure 1) and asks questions to engage students to the topic. For example, "If the connection between brain and eye is disconnected, what happens?” A student responds, “Optical illusions.” As a student continues reading about senses and their responses to stimuli, another student can raise another question, “How does the brain help you perceive your body?” Referring to the reading, the teacher adds, “The brain reads and uses the information through sending stimuli to the brain by chemical and electrical signals in three ways: short-term, working, and long-term memory.” Then, the teacher asks about how things stocked in a long term, and students provide answers such as patterns, language, frequency, and depending on how important they are or how they are important.

Plan and carry out an investigation- PLAN & DO (30 minutes + Homework). To answer the research question, students use the materials to collect the data and answer the research question. The students use “a set of cards numbered 1 through 9, a set of memory letter cards, paper, and timer.” To determine what type of data you need to collect, students are suggested to think about the following questions: What kind of information can you get from the person telling you about what is on the card? What type of measurements or observations will you need to record during your investigation?

During the data collection, students may think that people may easily remember or memorize the shorter words than the longer words. For example, many students state that people may remember “cat” easier than “tce.” The teacher reminds students to determine how many sets of data they need to collect and whether they can generalize to all people or not.

Students should be advised not to collect data from three people that would not be helpful to generalize the results to the whole population. For this investigation, students are suggested to collect data out of class from the adults and bring it to the next class for discussion. Students organize nine cards with numbers and letters (Table 1) for three sets of data collection from 50 people (25 females and 25 males) betweetn the ages of 18-30. The sets of cards are arranged according to the difficulty level including only random letters, only random numbers, and a mix of letters and numbers with seven, 10, and 15 digits. The participants are given 30 seconds to see a card and 10 seconds to tell what they see. For safety precautions, students aim to collect data from the people who are at least high school graduates without any disability. The students also aim to prepare a silent environment to reduce the errors and any misunderstandings during the data collection process. The students record the number of letters or numbers remembered, in order, on each set of cards according to gender. The results are represented in Table-2.

Table 1

Sets of cards with numbers and letters

	Set-1	Set-2	Set-3
Card-1	KPSYHRM	XPİYFWQBVH	URHGAISLNXFZEZV
Card-2	6602935	7308492165	734130752845729
Card-3	S1TY3M4	G8YU7ĞAT50	X47TZ5U93R16SLA

Students analyze the data to show differences between groups, trends over time, or relationships between variables and identify the significant features within the data. The data is analyzed to explain how the participants recall the numbers, letters, and their combination

Table 2

Participant	SET #1			SET #2			SET #3			Participant	SET #1			SET #2			SET #3		
Women#	C-1	C-2	C-3	C-1	C-2	C-3	C-1	C-2	C-3	Men#	C-1	C-2	C-3	C-1	C-2	C-3	C-1	C-2	C-3
W1	7	7	7	9	10	9	6	9	10	M1	7	7	7	10	8	9	13	15	14
W2	7	7	7	6	10	10	11	10	7	M2	7	7	4	7	6	10	10	8	11
W3	7	7	7	10	10	10	8	15	10	M3	7	7	7	9	10	10	15	15	14
W4	7	7	7	9	5	10	14	14	15	M4	7	7	7	10	10	10	12	15	9
W5	7	7	7	9	10	10	11	14	15	M5	7	7	7	10	10	10	15	10	11
W6	7	7	2	8	5	3	9	7	4	M6	7	7	4	10	10	10	9	10	5
W7	7	7	7	10	10	10	5	15	11	M7	7	7	7	6	10	10	8	2	5
W8	7	7	7	10	10	10	13	10	9	M8	7	7	7	10	10	10	10	6	7
W9	7	7	0	10	10	10	8	10	7	M9	7	7	7	10	10	4	9	6	14
W10	7	7	7	3	6	7	10	9	4	M10	7	7	7	8	10	8	11	8	7
W11	7	7	7	3	4	4	15	10	6	M11	7	7	7	8	10	10	7	4	5
W12	7	7	7	6	10	2	2	6	5	M12	7	7	7	7	8	10	8	10	12
W13	7	7	7	10	10	10	9	8	15	M13	7	7	7	10	10	10	7	15	8
W14	7	7	7	10	10	8	4	8	6	M14	7	7	7	10	10	8	4	8	6
W15	7	7	7	8	10	10	6	10	7	M15	7	7	7	8	10	10	6	10	7
W16	4	7	7	4	9	10	9	11	4	M16	7	7	7	10	10	10	3	11	7
W17	7	7	7	7	10	4	15	15	4	M17	7	7	2	10	10	10	6	6	2
W18	7	7	7	7	10	3	4	11	9	M18	5	7	2	4	9	8	9	15	1
W19	3	7	7	7	10	4	1	8	11	M19	7	7	4	8	10	10	2	7	7
W20	7	7	7	3	4	10	6	3	1	M20	7	7	7	10	10	10	15	6	15
W21	7	7	6	10	10	10	15	13	6	M21	7	7	7	7	10	3	7	8	3
W22	7	7	7	10	10	4	9	5	12	M22	7	7	0	10	10	10	6	10	12
W23	7	7	7	8	10	10	6	2	3	M23	7	7	7	6	10	10	9	15	8
W24	7	7	7	10	10	10	9	9	9	M24	7	7	4	10	10	10	13	11	7
W25	7	7	3	7	10	8	12	7	14	M25	7	7	7	10	7	7	10	7	5

differently based on gender variable. Students are expected to present their results to the other groups in a poster or paper format in the next lesson.

Whole-class discussion- SHARE & REFLECT (50 minutes). Students are asked to present their results to make their work visible. During the presentation, students need to explain the goal of the investigation, their answers to the question, their interpretation of data, and the scientific rationale of their results. A sample poster prepared by a student group is presented in Figure 2.

After listening to students' presentations, the teacher can evaluate and reflect on what students have done during the investigation. The teacher starts Socratic discussion through asking open-ended questions to encourage students to critique each other's ideas by using the evidence from the investigation.

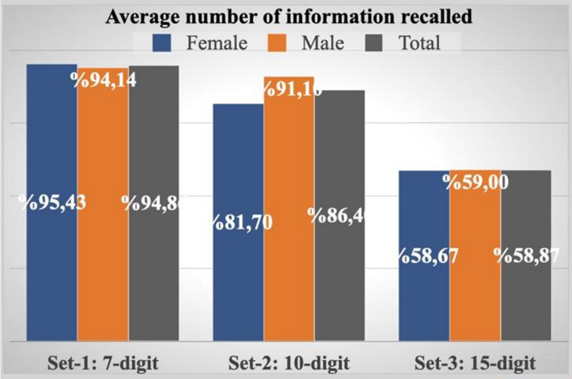
Figure 2

A sample presentation to answer the question.

Goal: To explain how the amount and order of information affect memory

Answer: As the number and complexity of letters or numbers increase from seven-digits to 15-digits, it will be more difficult to keep the information in short-term memory for both males and females.

Interpretation of data:



The data includes the average number of information recalled for seven-digit (set-1), 10-digit (set-2), and 15-digit (set-3) only letter, only number or mixed letter and number sequence in their short term-memory for 10 seconds. The graph suggests that for seven-digit letters, the participants (50 people) keep 94.86% (6.64 / 7) of the information on set-1; for 10-digit information, 86.4% of the information can be kept for set-2 information. For 15-digit information, the participants can remember 58.87% (8.83 / 15) of the information shown on set-3.

Scientific rationale

The interpretation of data supports the answer that the percentage of the information recalled decreases as the complexity of the information increases. This interpretation is based on the way that the brain reads and used the information in short-term memory for only a few seconds.

An example discussion is provided below:

Teacher: What was the main idea behind this investigation?
Student-1: Memory.
Teacher: Why are patterns important to memory?
Student-2: Easy to remember.
Student-3: Brain wants to see patterns.
Teacher: Who uses patterns?
Student-4: Patterns in psychology and art.

Table 3

Average of information recalled for each set.

			Card-1	Card-2	Card-3	
		Number	KPSYYHRM	6602935	S1TY3M4	**Total**
Set-1: 7-digit	Female	25	6.72	7.00	6.32	6.68 / 7
	Male	25	6.92	7.00	5.84	6.59 / 7
	Total	50	6.82	7.00	6.08	6.64 / 7
			XPiYFWQBVH	7308492165	G8YU7ĞAT50	
Set-2: 10-digit	Female	25	7.76	8.92	7.84	8.17 / 10
	Male	25	8.72	9.52	9.08	9.11 / 10
	Total	50	8.24	9.22	8.46	8.64 / 10
			URHGAISLNXFZEZV	734130752845729	X47TZ5U93R16SLA	
Set-3: 15-digit	Female	25	8.68	9.56	8.16	8.80 / 15
	Male	25	8.96	9.52	8.08	8.85 / 15
	Total	50	8.82	9.54	8.12	8.83 / 15

In the first part of the discussion, the teacher encourages students to explain how patterns as a crosscutting concept help them explain the function of memory. The teacher can also talk about the work of scientists such as the selection of sample size and the number of trials when they are conducting the investigations.

Teacher: Let's talk about sample size. How many people do you test?

Student-1: The results can be applied to all people.

Student-2: We have five subjects, can we say our results could be implemented all people?

Student-3: No.

Teacher: You need to look at who your results can be applied.

Student-4: For example, based on gender, ethnicity?

Teacher: It can be based on age, gender, or ethnicity, and the results will only be applied to that sample.

Through this discussion, the teacher warns students to consider the sample size and explain whether their results will be applied to the whole population or not.

Conclusion

Argumentation as a scientific practice emphasizes students` engagement in exploration and explanation that are essential for learning through introducing the task, planning, and carrying out investigation, and whole-class discussion (Sampson et al., 2013). After the task is introduced to the students (step-1), students are asked to develop a design to collect and analyze data to generate a tentative argument (step-2). In this investigation, students needed to collect data outside-of class from people within the 18-30 age group as homework. After students collect and analyze data, they present and discuss their results during the interactive discussion session (step 3): students listen to findings and discuss the strengths and weaknesses of each group's results. In further studies or lesson tasks, the data collection and analysis could be integrated into classroom instruction for an additional one or two class hours.

This lesson shows that this three-phase instructional sequence is an effective way to integrate the requirements of Next Generation Science Standards addressing scientific practices, core ideas, and crosscutting concepts and enhance student voice using literacy skills such as graphical or visual models, talking, and writing (NGSS Lead States, 2013). In this lesson, participating student teachers conclude that the information processing becomes difficult as the complexity of the information increases. This lesson format guides pre-service teachers to practice teaching through argumentation and understand how science works.

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