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Teachers' perspectives on teaching science through an argumentation-driven inquiry model: A mixed-methods study

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A R T I C L E I N F O

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A B S T R A C T

This study aimed to better grasp science instructors' perspectives on the argumentation-driven inquiry (ADI) teaching model through a sequential exploratory mixed-methods approach. A random sample of 184 Saudi Arabian science teachers (96 males and 88 females) completed a questionnaire. In addition, seven science teachers volunteered to participate in semi-structured interviews. The results indicated that ADI was used by science teachers less frequently than expected. This is because of the widespread belief that inquiry-based instruction, when combined with argumentation, necessitates greater classroom time and effort. Additionally, respondents reported engaging in some form of ADI on a monthly basis, once a month. Consequently, it was suggested that science teachers' professional preparation and continuous development programs be re-evaluated to ensure that they are in line with the most recent science education standards and new approaches such as STEM, STEAM, and NGSS.

1. Introduction

The implementation of an inquiry approach can help students improve their critical thinking, reasoning, and conceptual understanding because of its association with scientific argumentation. Students who engage in scientific inquiry activities can grasp the concepts of science meaningfully [1]. Additionally, under the guidance of teachers, students can practice scientific argumentation to deepen their understanding of scientific phenomena by asserting, arguing, and providing evidence to support their claims and arguments. Therefore, scientific argumentation could be emphasized in inquiry instruction [2–6] to improve students' achievement and lead them to a better understanding of science disciplines. The association between the inquiry approach and argumentation constituted the argumentation-driven inquiry (ADI) teaching model, which is the focus of this study. According to Kaçar and Balım [7], the reason for the positive change in students' conceptual understanding when using ADI is that it presents an opportunity for students to explore information and use critical reasoning in these processes. This is consistent with the objectives of Saudi Vision 2030 and the Human Capacity Development Program.

In the ADI framework, eight stages are specified for teachers, and seven stages are specified by students' behaviours at each stage of the instructional model because the teacher's role in an ADI lab differs from that in regular laboratories. Table 1 includes the tasks that the teachers and students must complete and could be used as a guide when first attempting to implement the lab activities described in the teacher's guide. During ADI, students plan experiments, look for supporting information, and assess and interpret the results of the

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experiment [8] to improve their inference abilities in experimental investigations. Through ADI activities, students construct new information based on prior learning and substantiate their claims with evidence from experiments to develop thoughts and ideas [9]. The ADI approach instructs teachers and students on how to use questions to expand their thinking and organize knowledge [10, 11, p. 28] (Table 1).

We could argue that the Next Generation Science Standards (NGSS) emphasize the importance of inquiry approaches to learning and teaching. In addition, the integration of STEM education can improve students' higher-order reasoning and problem-solving skills. In addition, the NGSS emphasize the use of argumentation and inquiry as essential components of scientific and engineering practices, and instructors are encouraged to employ these strategies to engage students in scientific and engineering practices.

We might also argue that the combination of argumentation and inquiry-based teaching can be implemented within the context of STEM classrooms. Through this integrative approach, students can better understand concepts and reach meaningful learning [12,13]. To keep students interested in STEM-related future careers, the ADI may be taken into consideration while teaching science. The ADI may help students acquire higher-order skills, such as creating a claim, proving it with evidence, and arguing about what they have explored [14]. The ADI model includes essential skills for graduates of STEM programs, and they go hand in hand. Engaging in ADI could lead to students achieving better education in school. The importance of the ADI model in teaching is evident from the educational literature and the current research findings related to this study. For example, Schwartz, Sengul, and Enderle [14] examined in-service science teachers' use of ADI by exploring the basis of teachers' adaptation of the ADI model. The findings indicated that teachers' practices were influenced by their personal beliefs, including beliefs about teaching and learning science; by students' abilities; and by contextual factors such as district and state standards, curriculum, and testing. In addition, Arslan, Genç, and Durak [15] utilized a mixed-methods design to examine the effectiveness of the ADI model on pre-service science teachers' (PSTs) achievement, science process skills, and argumentation levels before and after the treatment. A focus-group interview was conducted to investigate their views of the model. The findings indicated that the ADI model positively impacted PSTs' science process skills and argumentation levels, as well as their knowledge of the science content covered in the activities. Moreover, the PSTs held a positive attitude towards using the ADI model in their classes and stressed that it helped with retention.

Studies indicate that Saudi students have low achievement scores on national and international standardized tests, such as the TIMSS [16] and PISA [17]. Interestingly, these studies also demonstrated that girls had better achievement scores than boys. Furthermore, studies have indicated that professional development programs still focusing on the traditional model of lecturing and demonstration. Other programs may focus on inquiry-based instruction without enhancing the integration of argumentation. Teachers play a critical role in the successful implementation of ADI since they are held responsible for the success of their students. Science education suffers when teachers are unable to incorporate ADI into their lessons; therefore, ADI processes must be thoroughly understood by teachers to be effective. As a result, the ADI may be initiated as a course of study in any new reform efforts in the educational system, especially in science-teacher preparation programs and continuous, professional development programs. We assume that teachers are already familiar with the ADI approach because it is incorporated into their preparation and professional development programs. Therefore, teachers could implement an ADI approach in order to improve their skills and meet the new expectations that have emerged as a result of the reform effort. Learning to think more scientifically can be taught using ADI in STEM education [18]. Thus, this mixed-methods study aimed to explore teachers' perspectives on teaching science using an ADI model.

2. Questions

The main question:
What are science instructors' perspectives on ADI instruction?
Sub questions.

1 To what extent do science teachers engage students in ADI throughout the academic year?
2 To what extent do science teachers use scientific argumentation in their teaching?
3 What are the challenges that impede the implementation of ADI in teaching science?

Table 1
The ADI teacher and student template [11, p. 28].

The ADI Part I: A template for teacher-designed activities to promote laboratory understanding	The ADI Part II: A template for students
1 Exploration of pre-instructional understanding through individual or group concept mapping	1. Beginning ideas: What are my questions?
2. Pre-laboratory activities, including informal writing, making observations, brainstorming, and asking questions	2. Tests: What did I do?
3. Participation in scientific activities	3. Observations: What did I see?
4. Negotiation phase I: writing personal accounts of scientific activity (e.g. writing journals).	4. Claims: What can I claim?
5. Negotiation phase II: sharing and comparing data interpretations in small groups (e.g. making a group chart)	5 Evidence: How do I know? Why am I making these claims?
6. Negotiation phase III: comparing scientific ideas to textbooks or other printed resources (e.g. writing group notes in response to others' focus questions)	6. Reading: How do I compare my ideas with those found in the textbook?
7. Negotiation phase IV: individual reflection and writing (e.g. presentation to a larger audience).	7. Reflection: How have my ideas changed?
8. Exploration of post-instructional understanding through concept-mapping	

4 Are there gender differences in teachers' responses with regard to the implementation, abilities, and challenges of incorporating ADI into science teaching?
5 How do the interviews with science teachers help explain students' engagement, teachers' implementation, and the challenges of conducting ADI in a science classroom?

3. Materials and methods

Fig. 1 shows the explanatory sequential mixed-methods design [19] used in this study. Data gathered in this manner must have relevance and significance to the study topic to explore teachers' perceptions. This study relied primarily on closed-ended questionnaires to collect the initial data and on semi-structured interviews for further data collection. This included science teachers expressing their thoughts on the implementation of ADI in the classroom and the challenges they experienced while doing so.

Phase 1 Phase 2.

A. Quantitative Phase

Quantitative data were generated through a structured questionnaire that was sent to 935 high-school science teachers through email in Riyadh province, Saudi Arabia. The sample of schools comprised 184 teachers who responded to the questionnaire; 88 of them were females and 96 were males. The responding participants formed about 20% of the community. All of the participants were regarded as having sufficient knowledge about the ADI approach as well as the argumentation concept. In addition, the qualitative data were collected through an interview with a sample of seven science teachers, who were purposively selected based on their responses to the closed-ended questionnaire. The qualitative section of the study considers the impact of gender, taking into account the gender segregation that is prevalent in K–12 schools in Saudi Arabia. Additionally, the authors have included years of experience and qualifications as important variables in their analysis, which allows for a more comprehensive examination of the topic. These variables are presented in a table, providing an expanded view of the study (see Table 2).

A modified version of Young's questionnaire was used to create the majority of items in the closed-ended questionnaire [20]. The researchers created an additional section in the questionnaire solely concerned with argumentation to further explore their learning about teachers' abilities to conduct ADI teaching activities. The new section was incorporated because of the inextricable linkages between argumentation and inquiry; inquiry incorporates argumentation abilities into its processes [9,21,22] to enhance deep learning. The modified questionnaire is divided into four sections. To aid comprehension, each of the four development areas is further divided into subsections. The questionnaire items were organized by theme and offered various options. Some of the choices were built using seven Likert-type statements: "every class" (*6 points*), "several times a week" (*5 points*), "once a week" (*4 points*), "two to three times a month" (*3 points*), "once a month" (*2 points*), "less than once a month" (*1 point*), and "not in any way, shape, or form" (*0 points*).

The criteria for determining the level of practice were as the following: "every class" >5.19 to 6; "more than once a week" >4.35–5.19; "once a week" >3.51–4.35; "once a month" >2.67–3.51; "less than once a month" >1.83–2.67; and "not at all" 1–1.83. For the other themes, there were 5-point Likert-type statements: "strongly agree" (*5 points*), "agree" (*4 points*), "undecided" (*3 points*), "disagree" (*2 points*), and "strongly disagree" (*1 point*). The first theme, "The extent to which science teachers engage students ADI over an academic year" included 21 items. The second theme, "The extent to which science teachers use scientific argumentation in teaching activities" included 12 items. The third theme, "Science teachers' capacity to execute ADI teaching activities" included eight items. Finally, the last theme, "Challenges that hinder science teachers from using ADI" included 12 items. The following parameters were used to determine the teachers' perceptions of their abilities: 1–1.80 "strongly disagree," 1.81–2.60 "disagree," 2.61–3.40 "neutral," 3.41–4.20 "agree," and 4.21–5 "strongly agree". The criteria for calculating the ranges of challenges on the 5-point Likert scale for the fourth theme were determined by calculating the range (5–1 = 4), further dividing by the greatest value of the scale (five), and obtaining the least value (4/5) = 0.80. The following classification of the ranges of mean values was used to determine the length of the cells for the fourth theme: 4.21–5 "main challenge," 3.41–4.20 "big challenge," 3.33–3.40 "moderate challenge," 2.61–3.33 "small challenge," 1.81–2.60 "very minor challenge," and 0–1.80 "no challenge."

The original questionnaire was translated into Arabic before the addition of the argumentation section. To guarantee that the content of the entire questionnaire was valid, it was sent out via several communication tools to 10 specialists in the fields of science

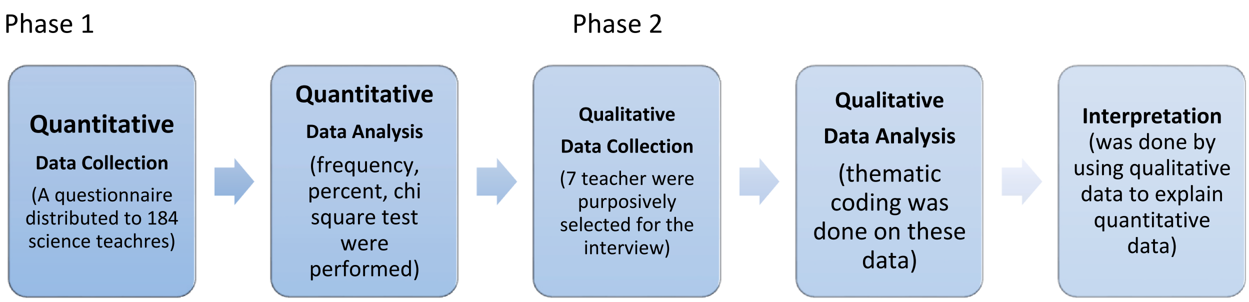

Fig. 1. The explanatory sequential mixed-methods design.

Table 2
The qualitative sample.

Participant	Gender	Qualification	Years of Teaching Experience
A1	Male	Master's	8
A2	Male	PhD	10
A3	Male	Master's	8
B1	Female	Master's	7
B2	Female	Bachelor's	12
B3	Female	Master's	25
B4	Female	Bachelor's	7

education, evaluation, and assessment. Following their feedback, a few changes were made to the wording and phrasing. To determine the reliability of the questionnaire, it was administered to a pilot sample of 35 teachers. Cronbach's alpha was calculated for each theme of the questionnaire, where the values for the first, second, third, and fourth themes as well as the overall value for the whole questionnaire were 0.82, 0.77, 0.81, 0.82, and 0.78 respectively. These values indicate that the reliability of the questionnaire and the themes fell within the range of acceptable to good, according to **Taber** [23].

B. Qualitative Phase

Following the completion of the quantitative questionnaire, a qualitative semi-structured interview protocol was conducted with a sample of seven science teachers, as shown in Table 2. The researcher's goal was to further explain or elaborate on some of the data obtained from the quantitative questionnaire in detail. During the interviews, the participants were given the opportunity to express themselves and reflect on their previous experiences [24]. Many questions were asked, including: "What do you know about inquiry?" "What do you know about argumentation?" "Do you believe that there is a relationship between inquiry and argumentation? Explain"; "To what extent do you involve students in ADI during an academic year?"; "To what extent do you use scientific argumentation in teaching activities?"; and "How would you describe your ability and challenges with regard to the implementation of ADI teaching activities?" The interview data were subjected to open and closed coding [25,26]. Saldaña [26, p. 3] defines a name as "a word or short phrase that symbolically assigns a summative, salient, and essence-capturing name to a portion of language-based or visual data" and "a word or short phrase that symbolically assigns a name to a portion of visual data." The researcher and other specialists collaborated on the coding process. In this process, the two coders obtained an agreement value of 87%.

To code the data (thematic analysis), a general coding process was utilized in which the data were evaluated and coded repeatedly to arrive at an impartial interpretation. According to Saldana [27], coding is the process of assigning a significant label to a textual component to facilitate the access of themes. The four primary themes from the analytical framework were incorporated into the coding of each tool for each teacher's data (personal, field of practice, field of remarkable results, and external domains) so that a code is only assigned to areas in which a change occurred, whether in knowledge or practices, to the development of new outcomes, or to the practice of new activities. The researcher relied on colors to define the four major themes, within each of which a code was assigned. Themes were generated as a result of the coding process.

4. Ethical issues

Ethical requirements provided by the Scientific Research Ethics Committee at King Saud University were met during this research.

5. Results

A. The Quantitative Results

The results are presented in five parts: (1) the extent to which science teachers engaged students in ADI throughout the academic year; (2) how much science teachers used scientific argumentation in their teaching activities; (3) the challenges that science teachers encountered when implementing ADI; and (4) the impact of gender (male and female) on teachers' responses with regard to the implementation, abilities, and challenges of incorporating ADI in science teaching.

Q.1 To what extent do science teachers engage students in ADI throughout the year?

This question explored the extent to which science teachers allowed students to practice ADI throughout the academic year. Based on teachers' responses demonstrated in Table 3, results indicated that teachers allowed their students to practice only five out of twenty-one ADI skills once a week; these skills include: 1) asking controversial questions about the natural and man-made worlds; 2) designing questions for experimentation in the science classroom; 3 (posing questions about properties, patterns, and inconsistencies in data lists; and 4) reading scientific texts that are appropriate for the grade level as well as interpreting ideas using tables, graphs, and displays, and 5) producing explanatory texts in a written or verbal manner with explanations and clarifications of ideas. On the other hand, the other 16 tasks were practiced by students only once a month.

Table 3
The extent to which science teachers involve students in adi during an academic year.

No.	Task		Not at all 1	Less than 1 a month 2	Once a month 3	Once a week 4	More than one a week 5	Every class 6	n	Weighted mean	Extent
1	Ask controversial questions about the natural and man-made worlds	f	7	19	53	21	58	24	182	3.97	Once a week
		%	3.8	10.4	29.1	11.5	31.9	13.2			
2	Design questions for experimentation in class	f	12	15	66	28	52	10	183	3.67	Once a week
		%	6.6	8.2	36.1	15.3	28.4	5.5			
3	Pose questions about properties, patterns, and inconsistencies in data lists	f	21	18	58	18	52	16	183	3.60	Once a week
		%	11.5	9.8	31.7	9.8	28.4	8.7			
4	Design forms and shapes as representations of events and regulations	f	21	23	67	17	45	10	183	3.39	Once a month
		%	11.5	12.6	36.6	9.3	24.6	5.5			
5	Represent and interpret phenomena in multiple forms	f	27	20	57	20	39	20	183	3.46	Once a month
		%	14.8	10.9	31.1	10.9	21.3	10.9			
6	Discuss limits, constraints, and precision models	f	41	25	54	15	36	12	183	3.09	Once a month
		%	22.4	13.7	29.5	8.2	19.7	6.6			
7	Decide data to be collected, tools required to collect them, and how to record measurements	f	25	25	60	17	42	14	183	3.37	Once a month
		%	13.7	13.7	32.8	9.3	23	7.7			
8	Decide how much data are required to produce reliable results, taking into account limitations and accuracy	f	49	2	63	16	36	13	179	3.15	Once a month
		%	27.4	1.1	35.2	8.9	20.1	7.3			
9	Plan practical experiments with independent and control variables	f	36	5	63	18	44	15	181	3.41	Once a month
		%	(19.9)	(2.8)	(34.8)	(9.9)	(24.3)	(8.3)			
10	Analyze data in a systematic manner and consider if data is consistent with assumptions	f	33	7	62	20	42	16	180	3.44	Once a month
		%	(18.3)	(3.9)	(34.4)	(11.1)	(23.3)	(8.9)			
11	Use graphics, tables, forms, statistics, and accounts to collect and summarize data and discover relationships between variables	f	44	7	63	20	35	11	180	3.16	Once a month
		%	(24.4)	(3.9)	35	(11.1)	(19.4)	(6.1)			
12	Assess strength of conclusions derived from various data using appropriate methods and techniques	f	50	2	64	21	33	10	180	3.08	Once a month
		%	(27.8)	(1.1)	(35.6)	(11.7)	(18.3)	(5.6)			
13	Formulate explanations for the phenomena using scientifically-proven theories	f	36	5	74	15	36	15	181	3.30	Once a month
		%	(19.9)	(2.8)	(40.9)	(8.3)	(19.9)	(8.3)			
14	Use evidence and scientific models to support or reject explanations of phenomena	f	37	8	62	19	40	15	181	3.34	Once a month
		%	(20.4)	(4.4)	(34.3)	(10.5)	(22.1)	(8.3)			
15	Diagnose potential vulnerabilities for caption explanations	f	42	7	64	21	35	11	180	3.18	Once a month
		%	(23.3)	(3.9)	(35.6)	(11.7)	(19.4)	(6.1)			
16	Build arguments about how data support claims	f	50	4	58	20	33	16	181	3.17	Once a month
		%	(27.6)	(2.2)	32	11	(18.2)	(8.8)			
17	Diagnose whether potential determinants in scientific controversies are appropriate to students' aptitudes and discuss them using thinking explanations and proofs	f	52	6	72	13	26	11	180	2.93	Once a month
		%	(28.9)	(3.3)	40	(7.2)	(14.4)	(6.1)			
18	Realize that scientific arguments are responsible for data and recognize it with examples	f	47	7	63	20	33	9	179	3.07	Once a month
		%	(26.3)	(3.9)	(35.2)	(11.2)	(18.4)	5			
19	Use words, tables, and drawings to communicate or ask questions about the system under study	f	34	6	67	20	38	14	179	3.36	Once a month
		%	(19)	(3.4)	(37.4)	(11.2)	21.2	(7.8)			
20	Read scientific texts that are apt for the grade level and interpret ideas using tables, graphs, and displays	f	28	4	58	23	42	25	180	3.68	Once a week
		%	(15.6)	(2.2)	(32.2)	(12.8)	(23.3)	(13.9)			
21	Produce explanatory texts in a written or verbal manner with explanations and clarifications of ideas	f	37	5	63	20	34	21	180	3.40	Once a week
		%	(20.6)	(2.8)	35	(11.1)	(18.9)	(11.7)			
Total										3.34	Once a month

Q.2 To what extent do science teachers use scientific argumentation in their teaching?

Answering this question allowed us to explore the extent of science teachers' implementation of scientific argumentation in science teaching. Table 4 illustrates how science teachers use scientific argumentation components in their lesson plans when conducting teaching activities. The weighted mean ranged from 1.61 to 1.80, indicating that science teachers think that their implementation of scientific argumentation in teaching fluctuates between "sometimes" and "rarely."

Q.3 What are the challenges that impede the implementation of ADI in teaching science?

Table 5 indicates the types of challenges that science teachers encounter when attempting to incorporate ADI into their science instruction. The results indicated that science teachers rated all challenges included in Table 5 as big or main challenges with eight items as main challenges and four items as big challenges. For example, the item "poor motivation among students" was deemed a main challenge from the teachers' viewpoint while "teachers insufficient scientific or pedagogical knowledge" represented a big challenge.

Fig. 2 indicates that science teachers only sometimes involved their students in ADI while their involvement of students in argumentation was rare (once a month), not as it was expected. Fig. 2 also indicates that they and their students faced main challenges in their implementation of ADI in teaching science. It also indicates that both male and female teachers hold the same perspectives about the implementation of ADI in teaching sciences.

Q.4: Are there gender differences in teachers' responses with regard to the implementation, abilities, and challenges of incorporating ADI into science teaching?

A chi-square test was performed to determine the extent to which science teachers involved students in ADI during an academic year and to test the impact of gender on engaging students in ADI activities. The results indicated no differences; there was no influence of gender on teachers' engagement of students in ADI activities. Similarly, there were no gender differences in the teachers' argumentation practices in science teaching.

With regard to the challenges that impede teachers from implementing ADI, a chi-square ($\chi2$) test was performed to explore the difference between male and female science teachers with regard to those challenges. Table 6 indicates that there were no differences in most of the challenges. However, differences were observed in three out of the 12 challenges, namely, "ADI needs more time," "challenges related to weak motivation among students towards ADI," and "challenges related to class time." Males rated low motivation as a major challenge whereas females rated it as a medium-to-major challenge. In contrast, male teachers considered that the short time allocated for ADI or ADI requiring more time to perform represented a small-to-big challenge whereas females considered it a big-to-main challenge. The expected counts for female teachers considering less class time or that ADI needs more time for

Table 4
The extent to which science teachers use scientific argumentation in teaching activities.

Activities		Rarely 1	Sometimes 2	Always 3	N	Weighted mean	Extent
1. I use argumentation to prove evidence.	f	75	74	32	181	1.76	Sometimes
	2. %	40.8	40.2	17.4			
3. I use justified argumentation during teaching.	f	89	66	26	181	1.65	Rarely
	4. %	48.4	35.9	14.1			
5. I use and train students to use counter-evidence of argumentation.	f	77	71	34	182	1.76	Sometimes
	6. %	41.8	38.6	18.5			
7. I train students to use controversial justification approaches.	f	71	82	29	182	1.77	Sometimes
	8. %	38.6	44.6	15.8			
9. I encourage students to rebut unimpressive evidence.	f	72	74	35	181	1.80	Sometimes
	10. %	39.1	40.2	19			
11. I tend to refute justification given by students.	f	82	74	26	182	1.69	Rarely
	12. %	44.6	40.2	14.1			
13. I encourage students to use proof in building argumentation.	f	97	57	27	181	1.61	Rarely
	14. %	52.7	31	14.7			
15. I try to address misconceptions among students.	f	81	69	30	180	1.72	Rarely
	16. %	44	37.5	16.3			
17. I encourage students to agree/disagree on appropriate positions.	f	72	80	28	180	1.76	Sometimes
	18. %	39.1	43.5	15.2			
19. I encourage students to critique others' arguments.	f	69	82	31	182	1.79	Sometimes
	20. %	37.5	44.6	16.8			
21. I realize and can teach students forms/structures of argumentation.	f	72	76	33	181	1.78	Sometimes
	22. %	39.1	41.3	17.9			
23. I use argumentation in science representation.	f	82	74	26	182	1.69	Rarely
Total						1.73	Sometimes

Table 5
The challenges that hinder science teachers from implementing ADI.

Challenges		Main challenge 5	Big Challenge 4	Medium Challenge 3	Light Challenge 2	No Challenge 1	N	Mean	SD	Level
1) Poor motivation among students	f	40	107	22	13	0	182	4.956	.7924	Main challenge
	2) %	22	58.8	12.1	7.1					
3) Weak abilities in students	f	25	106	28	23	0	182	4.731	.8534	Main challenge
	4) %	13.7	58.2	15.4	12.6					
5) Teachers with insufficient scientific knowledge	f	13	80	45	63	0	181	4.127	.9777	Big challenge
	6) %	7.2	33.10	24.9	34.8					
7) Teachers with insufficient pedagogical knowledge	f	8	51	46	77	0	182	3.945	.9386	Big challenge
	8) %	4.4	28	25.3	42.3					
9) Issues related to classroom management	f	13	67	45	57	0	182	4.198	.9659	Big challenge
	10) %	7.1	36.8	24.7	31.3					
11) Insufficient class time	f	32	101	16	31	0	180	4.744	.9462	Main challenge
	12) %	17.8	56.1	8.9	17.2					
13) Inquiry is too time-consuming to prepare	f	36	105	25	16	0	182	4.885	.8229	Main challenge
	14) %	19.8	57.7	13.7	8.8					
15) Class size is too large	f	31	102	14	32	0	179	4.737	.9500	Main challenge
	16) %	17.3	57	7.8	17.9					
17) Inability to assess students in the survey	f	24	95	37	27	0	183	4.634	.8909	Main challenge
	18) %	13.1	51.9	20.2	14.8					
19) Lack of suitable lessons for inquiry teaching	f	23	71	48	41	0	183	4.415	.9734	Main challenge
	20) %	12.6	38.8	26.2	22.4					
21) Scarcity of necessary materials for inquiry lessons	f	31	106	27	19	0	183	3.814	.8376	Big challenge
	22) %	16.9	57.9	14.8	10.4					
23) Poor motivation among teachers	f	27	109	24	20	0	180	3.794	.8303	Big challenge
	24) %	15	60.6	13.3	11.1					
								4.42		Main challenge

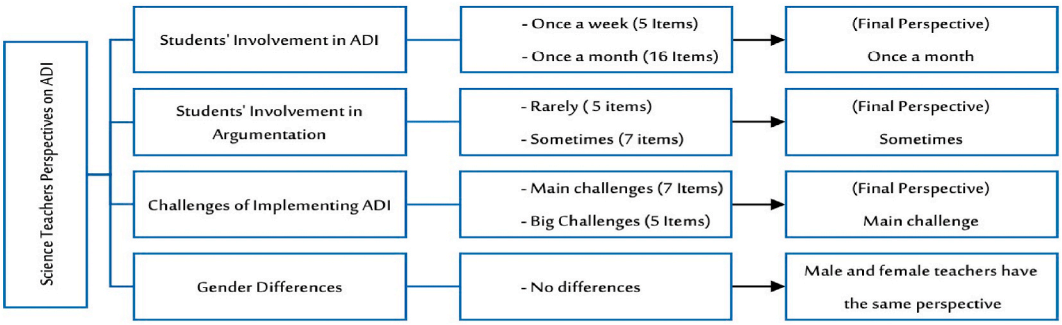

Fig. 2. Representation of teachers perspectives on their use of adi in teaching sciences.

preparation and execution as a main or big challenge were greater than the actual counts, while the case for male teachers was the opposite, where the expected counts were less than the actual ones. Therefore, female teachers consider weak motivation to be a major challenge. Regarding the differences among teachers with respect to gender in consideration of weak motivation among students towards the ADI teaching method, the chi-square (2) test revealed that there were significant differences between male and female teachers. The expected counts for male teachers considering weak motivation as a main or major challenge were greater than the actual counts, whereas the case for female teachers was the opposite; the expected counts were less than the actual ones. This indicates that male teachers consider weak motivation to be a major challenge.

Table 6
The chi-square test for the differences in challenges that impede teachers' view about their abilities to perform adi teaching activities according to gender.

Challenge			1.00	2.00	3.00	4.00	Total	(χ^2)	p
Weak motivation	Male	Count	4	5	58	26	93	12.884[a]	.005
		Expected Count	6.7	11.3	54.5	20.6	93.0		
	Female	Count	9	17	48	14	88		
		Expected Count	6.3	10.7	51.5	19.4	88.0		
	Total	Count	13	22	106	40	181		
		Expected Count	13.0	22.0	106.0	40.0	181.0		
Les class time	Male	Count	26	12	39	16	93	22.827[a]	.000
		Expected Count	16.1	8.3	52.0	16.6	93.0		
	Female	Count	5	4	61	16	86		
		Expected Count	14.9	7.7	48.0	15.4	86.0		
	Total	Count	31	16	100	32	179		
		Expected Count	31.0	16.0	100.0	32.0	179.0		
ADI needs more time	Male	Count	13	18	44	18	93	13.424[a]	.004
		Expected Count	8.2	12.8	53.4	18.5	93.0		
	Female	Count	3	7	60	18	88		
		Expected Count	7.8	12.2	50.6	17.5	88.0		
	Total	Count	16	25	104	36	181		
		Expected Count	16.0	25.0	104.0	36.0	181.0		

B. The qualitative results

Q.1 What do you know about inquiry?

To gain deeper insight into science teachers' knowledge of the concept of inquiry, they were asked to give a glimpse into their perspective of the concept. The answers indicated that all the science teachers' interviewees had a superficial understanding of this concept. For instance, teacher A1 (an intermediate male teacher with 7 years of teaching experience) stated that inquiry is "a type of teaching strategy" without giving more details while teacher B2 (a high-school female teacher with 12 years of teaching experience) stated, "I don't know the definition of inquiry, but I think it is a type of teaching method." Interestingly, teacher A3 (an elementary-school male teacher with 10 years of experience) stated, "Inquiry is the opposite of deduction, induction."

Q.2 What do you know about argumentation?

Most interviewees believed that argumentation is a kind of dispute in which one person opposes another's ideas or opinions. For example, Teacher A1 stated, "Argumentation is a type of critique and defence." In the same context, Teacher A2 (an elementary-school male teacher with 10 years of experience) stated, "It is kind of a mismatch of ideas or opinions." However, a female teacher (B2) (a high-school teacher with 12 years of experience) stated, "I have heard about argumentation; however, I do not know the steps of the strategy."

Q.3 Do you believe there is a relationship between inquiry and argumentation? Explain.

Most interviewees believed that there was a link between inquiry and argumentation. However, this link seemed ambiguous among teachers. For example, Teacher A1 stated, "I do not have a clue. This might be included in the inquiry process. I had not heard about it." In the same context, Teacher B2 (a high-school female teacher with 12 years of experience) stated, "I believe so [there is a relationship] since argumentation arises from inquiry."

Q.4 To what extent do you involve students in ADI during an academic year?

All interviewed science teachers agreed that they did not engage students in ADI activities in consequential steps as they lacked fundamental knowledge about argumentation and inquiry. Interestingly, Teacher B1 (a female high-school teacher with 11 years of experience) stated, "I am focusing only on argumentation without following specific phases."

Q.5 How would you rate your ability to perform ADI?

We asked the interviewees to rate themselves (1–10) in terms of performing a model science lesson for their colleagues without reading the strategy. Their ratings fluctuated from 0 to 5, except for one teacher who rated his ability as 7 out of 10, ensuring that he could implement ADI after reading authentic references and practicing ADI.

Q.6 What are the challenges impeding science teachers from implementing ADI in science teaching?

Science teachers' responses to this question were classified into four themes:

The first theme, teacher-related challenges, included teachers' deficiencies in teaching science through ADI and their poor motivation. Interestingly, all the interviewed teachers agreed that they lacked the essential competencies required for performing an ADI in teaching science. A teacher (B2) stated when asked about the challenges, "I eventually do not grasp the concept of ADI, so I do not know more about the challenges that impede teachers from the implementation of ADI in science classrooms."

The second theme, student-related challenges, indicated that challenges related to students are centered on three factors: students' repeated absence, low motivation towards participation in activities, and the probability that the use of argumentation may throw the class into disarray. Even though science teachers considered these to be the main challenges, the researchers believe that talented teachers could overcome these challenges by enhancing students' motivation and increasing their attendance. A2 teacher (an elementary-school male teacher with 20 years of teaching) stated, "I could enhance students' motivation through utilizing social media such as Telegram."

The third theme, school environment-related challenges, included three factors that impeded science teachers from implementing ADI: large classes (two teachers indicated that they have '65 and 52 students per class), a lack of school equipment, and an educational environment which is not suitable for this kind of teaching model.

The fourth theme, science curriculum-related challenges, included the intensity of science content, curriculum mismatching with the ADI model, and a lack of time allocated for science classes since ADI requires more time compared to other traditional methods.

Teachers who participated in the interviews and were asked about challenges in the implementation of ADI teaching activities indicated that the items included in Table 5 represented actual challenges to their implementation of ADI. The interview findings also revealed that teachers confronted major obstacles in the adoption of inquiry-based education and/or argumentation in the classroom when it comes to teaching science. According to them, the difficulties stemmed from the 'short time allotted for teaching science courses in the school calendar and the number of students in each classroom'.

C. Mixed-Methods Integration

The researchers re-examined the integrated interview findings and considered the value of mixed methods in explaining the statistical findings to answer the last research question. The use of mixed methods provided a better explanation, as shown in Table 7. The quantitative results and the associated qualitative findings that explain these results are aligned in the table. The first two research questions, concerning teachers' opinions of ADI and obstacles to its application, were the main focus of the integrated analysis. The

Table 7

A Mixed-Methods joint display of the integration of quantitative and qualitative data to explain adi.

Quantitative Results	Qualitative Results	Mixed Methods Integration
1) Students' engagement in ADI throughout the academic year (M = 3.34). Teachers engage students in ADI activities once a month. Therefore, the engagement level is not sufficient.	All science teachers interviewed had a consensus that they did not engage students in ADI activities in consequential steps since they lacked fundamental knowledge about argumentation and inquiry.	Mixed methods gave a deeper insight into how teachers engage their students in ADI throughout the academic year. The qualitative part indicates that all science teachers did not engage their students in ADI activities as a whole process, but teachers implemented some of the ADI model processes individually or part from other steps.
2) Science teachers' implementation of scientific argumentation in science teaching (M = 1.73), which means that teachers sometimes used scientific argumentation in science teaching.	Most of the teachers interviewed considered the scientific argumentation a kind of dispute without realizing the consequential processes of this strategy.	Even though the quantitative part indicates that science teachers sometimes implemented scientific argumentation in teaching science, the qualitative section indicates the lack of teachers' comprehension concerning argumentation and its sequential processes. Also, science teachers rated themselves as a novice with regard to the knowledge and skills pertaining to argumentation. This helps researchers explain how science teachers practice argumentation from their points of view.
3) Challenges that hinder science teachers from implementing ADI (M = 42). Accordingly, the challenges were classified as main challenge.	Science teachers classified their challenges into three groups: teacher-related challenges; students-related challenges; school environment-related challenges; and science curriculum-related challenges.	The qualitative part provided a better comprehension of the challenges that encountered science teachers while performing ADI such as teachers' deficiency in ADI skills, teachers' and students' low motivation, and other challenges concerning the school environment and science curriculum.
4) Differences in challenges that impede teachers' view about their abilities to perform ADI teaching activities according to gender: no gender differences were found except for the challenges of implementing ADI. These differences were found in three challenges which are weak motivation, less class time, and more time required for ADI	The qualitative section does not find gender differences as the teachers interviewed had a consensus with regard to the lack of knowledge and skills pertaining to using ADI as a teaching model.	The qualitative part supports the results of the quantitative part with regard to the lack of gender differences in the first two themes, namely students' engagement in ADI and teachers' practices of argumentation. In addition, the qualitative results agreed with the quantitative results in most of the challenges except three challenges as shown in Table 5.

third research question concerned teacher experience. Although the participants' levels of experience varied, instrument analysis found no relationship between experience and CLT attitudes. However, when choosing representative participants for the subsequent qualitative phase, experience level was crucial. Thus, the findings related to experience served to link the quantitative and qualitative phases. The data were coded using thematic analysis in which they were repeatedly reviewed and coded to produce an unbiased analysis. The researchers used colors to identify the four overarching themes, within each of which a code was only given for the aspects in which a change occurred, whether in knowledge or practices, the appearance of new outcomes, or the practice of new activities.

6. Discussion

The questionnaire results related to "the extent to which science teachers involve students in ADI during an academic year" indicated that science teachers rarely allowed their students to perform ADI activities, that is, once a month. Previously published findings [28–30] asserted the importance of inquiry-based instruction and demonstrated that it could improve academic performance, which was incompatible with these findings. Student participation in pronounced inquiry activities, which were identified as one of the five fundamental criteria of inquiry-based learning, was found to be essential. The interview results indicated that science teachers did not have a clear perspective on inquiry, argumentation, or ADI. This ambiguous understanding could be due to insufficient preparation programs for pre-service science teachers or professional development programs for in-service teachers. Teachers were unable to define inquiry precisely eventhough they claim that they have a clear vision of this approach. As a result of their unclear vision of ADI, they were not sure whether they were able to properly use or implement this approach in teaching sciences. These results were consistent with those of previous studies, which indicated that Saudi Arabian science curricula did not include sufficient skills or knowledge related to ADI [31].

Regarding the "extent to which science teachers use scientific argumentation in teaching activities," teachers indicated using argumentation once a month. This answer proved that science teachers did not see argumentation as important, they might not have the ability to use this approach, or they may not have enough knowledge related to argumentation. Furthermore, research has stressed [8,32] the relevance of ADI in supporting students in attaining scientific knowledge (as well as science learning).

During the interview, the teachers were asked about their abilities to engage in ADI teaching activities in a classroom setting. The majority indicated that they were unsure of their capacity to utilize arguments because they were concerned about "throwing the class into disarray." Llewellyn [33] argues that teachers who possess strong inquiry abilities in addition to critical thinking and argumentation skills are better able to propose, support, critique, refine, justify, and defend their positions on issues, and in doing so, would help students assimilate and evaluate existing scientific information as well as generate new knowledge. Therefore, ADI will help teachers perform better in their studies and jobs in their respective fields. According to Llewellyn [33], scientific argumentation is deemed a critical component of scientific inquiry since it can improve students' academic performance and lead them to better knowledge of disciplines such as science. As a result, it has been suggested [2,3,5] that scientific argumentation might be emphasized in inquiry-based professional development programs [5,6]. Studies [3] found that ADI outperformed standard laboratory instruction in terms of boosting pre-service science teachers' achievement as well as their scientific processing capabilities. ADI can also increase students' ability to assimilate scientific knowledge and, hence, improve overall achievement.

The interview findings revealed that teachers reported that they confronted major or substantial obstacles in adopting inquiry-based education and/or argumentation, and eventually ADI, when it comes to teaching science. According to them, the difficulties stemmed from the "short time allocated for teaching science courses in the school calendar." Another possible explanation for these difficulties is students' motivation to participate in ADI [34]. Students who are more confident in their abilities are more likely to engage in ADI whereas those who are less confident in their abilities regard inquiry-based argumentation as less significant [35] and therefore are less likely to be engaged in ADI. Other studies [36] related to challenges concerning the learning environment also included teachers' attitudes, desires, and curriculum among those challenges that impede the implementation of ADI in science teaching and learning [37].

Concerning quantitative results related to the challenges that impede science teachers from using ADI, the results indicated that science teachers faced major challenges in their efforts to implement ADI. For instance, poor motivation among students is considered the main challenge whereas insufficient scientific or pedagogical knowledge represents a major challenge. One possible explanation for these difficulties is that teachers lack the fundamental knowledge and skills necessary for the successful implementation of ADI. The results showed that teachers did not reach a consensus on the definition or general meaning of scientific argumentation. O'Keefe [38] distinguished between "making an argument and having arguments." He considered making arguments "a rhetorical act but constructed by the lone individual and a technical process of finding the most ideal connection between a claim and evidence to support the claim." O'Keefe [38] argued that argumentation might not be considered a two-sided debate aimed at seating a winner or loser; rather, it may be structured to help individuals reach the truth. In addition, argumentation was described [39, p. 150, 40]. As the Rogerian argument is associated with communication, understanding, cooperation, and truth-seeking, the traditional or Aristotelian argument is associated with pat formulae, tricking, winning, refuting, intimidating, and prevailing over an opponent. Researchers explain argumentation as a methodical and constructive way to try to get to the truth.

7. Conclusion

This study aimed to investigate the perspectives of science teachers on the implementation of ADI teaching models in science classrooms. The findings revealed that science teachers encountered several difficulties when it came to implementing scientific ADI in their classrooms. Consequently, they rarely incorborated ADI in their science teaching practices. The findings also highlighted the relevance of ADI as a fundamental component of effective teaching and learning in STEM courses. The use of ADI allows learners to follow in the footsteps of scientists while simultaneously developing science and research abilities. Scientific ADI may help foster a more positive scientific culture, promote knowledge of scientific methods and technical terms, as well as lead to a greater understanding of concepts, trends, and positive attitudes. ADI teaching and learning emphasize developing inquiry-based learning skills by using exploratory laboratories and developing argumentation skills to improve students' science literacy. This method AAencourages students to ask questions, design experiments, and offer written and oral arguments. ADI uses logic and experimentation which may help students make better scientific arguments by using laboratory experience. This is because ADI requires students to employ inquiry (how to acquire and assess data) and reasoning skills that support arguments with evidence to be able to build and present arguments during interactive argumentation sessions. Students must devise and apply their own systems to gather and analyze data, form and express opinions, provide evidence for their claims, report their findings, and peer evaluate others' work. Through ADI, students learn how to conduct a scientific inquiry by explaining natural events using scientific methods.

We believe that our study makes a significant contribution to the literature because it sheds light on science teachers' perspectives on the implementation of ADI and the challenges that they face while teaching science using ADI. This would allow researchers to design and conduct professional development programs to enhance teachers' abilities and skills to successfully use this approach in teaching the sciences. Also, recognizing the challenges would enable policymakers to overcome these challenges. In addition, ADI is deemed significant for the current reform and development in the field of STEM and STEAM education. Focusing on science teachers in Saudi public schools would help cope with modern STEM courses, enhancing their teaching abilities and their students' talents. Teachers can acquire scientific ADI skills and talent from professional development program specialists. This study also highlights the difficulties of implementing ADI in science classes at all levels of public education.

8. Limitations and future directions

This study does not come without shortcomings. First, this study is a self-reported type of study. However, it was necessary to produce descriptions of teachers' perspectives on ADI and the challenges facing them when teaching through this approach. Secondly, more research studies are required to investigate teachers' conceptions of ADI, their abilities to implement ADI in their teaching of sciences, and the efficacy of ADI in enhancing student achievement and their argumentation skills. Thirdly, teachers' competencies and attitudes pertaining to ADI may also be studied after conducting professional development programs using mixed methods such as questionnaires, interviews, and observations. Furthermore, research on the inclusion of argumentation and inquiry abilities in science curricula is equally important. Finally, studies exploring the impact of ADI training on student achievement and attitudes towards STEM are recommended. It is also very important to know students' attitudes toward the use of the ADI approach in teaching science subjects, especially its impact on their involvement in the learning processes and then on their accomplishments and skills.

Ethical approval

Ethical approval for this study was obtained from the Permanent Committee for Scientific Research Ethics at King Saud University (APPROVAL NUMBER: KSU-HE-22-793).

Author contribution statement

Yousef F. Alfarraj; Abdulwali H. Aldahmash; Sozan H. Omar: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper

Data availability statement

Data will be made available on request.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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