STUDY OF EFFECTIVENESS OF THE ARGUMENT-DRIVEN INQUIRY PEDAGOGY IN SCIENCE CLASSROOMS OF INDIA

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Implementation of Argument-driven Inquiry (ADI) pedagogy in India would face many impediments due to the detrimental alliance of the curricula with its transaction time, infrastructural limitations, and the evaluation system. The teaching-learning system with the sole aim of securing high marks is more prone to rote learning. Hence, we attempted to modify the ADI according to the Indian context, and try out the pedagogy for science classrooms in Indian schools. For this purpose, studies were conducted in the form of workshops for both Physical and Biological Sciences in schools of rural and urban sectors. We have narrated the experiences gathered from the Biological Science workshops in the form of a first-hand case study in this paper. It has been observed from the studies that notwithstanding the impediments, this pedagogy can be very useful for the teachers and the all-important students if it can be judiciously amalgamated with the ongoing teaching strategies within the constraints of time, space and infrastructure.

Keywords: Argument, Inquiry, Pedagogy, Classroom, India, School, ADI

Introduction

Science is the process of generating knowledge thorough investigation into the natural world. Any investigation starts with a question. In finding a solution, we gather data, analyse, argue, and validate a hypothesis. Spirit of inquiry, collaborative work, argumentation, and communication are the fundamental forces driving the scientific community. Every school should bring these in regular practice for all its students from early childhood to develop a scientific temper.

In India, the National Curriculum Framework has set the aim for Indian science education to develop creativity, flexibility, and inventiveness in every student of India (National Council of Educational Research and Training, 2005). However, still, we are far from achieving the goal (National University of Educational Planning and Administration, 2014). NCERT formed a "National Focus Group on Teaching of Science" according to their report published in 2006 "... science education, even at its best, develops competence but does not encourage inventiveness and creativity..." (Kumar, et al., 2006). In the last 40 years, lots of researches on science education have come up with the best possible recommendations (Driver, 1975; Fraser, 1998; Hoidn, 2017; Kremer, et al., 2013; Kumar, et al., 2006; K. Kumar, et al., 2001; Larkin, et al., 1980; Lederman, 1992; Metcalfe, 2017; National Council of Educational Research and Training, 2005; National University of Educational Planning and Administration, 2014; Sampson, et al., 2010, 2015; Sarukkai, 2014; Sullivan, et al., 2017). However, India's real classroom situation remains largely unchanged (Chandran, 2014; Joy, 2014a; Ministry of Human Resource Development, 2016a; Sarangapani, 2014; Sarukkai, 2014; UNESCO Institute for Statistics Database. UIS. Stat., 2018). Various science education researchers, including (Duschl, 2008; Duschl and Osborne, 2002), have argued for shifting the model of classroom instruction away from the one-way transmission of ideas to models that *inter alia* lay stress on knowledge construction and validation through inquiry, provide increased opportunities to perceive natural phenomena, inspire engagement in critical thinking, and involvement in sharing those ideas with groups. These group activities target creating a classroom community to help students understand scientific explanations. However, in reality, teachers in Indian schools very seldom conduct experiments in classrooms; and even if it is ever done, the experiments are found to emerge mainly from the textbooks overlooking the needs of students, who end up as mere followers (Chandran, 2014; Sarangapani, 2014). They either follow or watch whatever they are shown. To conduct experiment-based learning in the classroom, the teachers and students need enough space and time to plan an experiment, design its structure, discuss the idea, record data, analyse; and all these pose significant problems (Chandran, 2014; Cheney, et al., 2006; Joy, 2014a; Kumar, et al., 2006; Muralidharan and Kremer, 2008; Sarangapani, 2014; Sarukkai, 2014) in case of overcrowded classrooms of Indian schools (Asian Development Bank, 2018; Cheney et al., 2006; Ministry of Human Resource Development, 2016b, 2016a; National University of Educational Planning and Administration, 2014; National University of Educational Planning and Administration, and Department of School Education and Literacy, Ministry of Human Resource Development, Government of India, 2016; UNESCO Institute for Statistics Database. UIS.Stat., 2018).

A well-known fact is, the practice of collaborative study, inquiry-based pedagogy, logical argumentation, and participation of students in setting goals to making decisions are a few of those crucial factors which play vital roles in gaining better student outcomes (Driver, 1975; Duschl, 2008; Duschl and Osborne, 2002; Kumar, et al., 2006; Lederman, 1992; Wellington, 1981). The USA, UK, and other developing countries have already implemented "inquiry," and "discovery" approaches in their curricula since the 1960s, but those also have their limitations. They faced logical, psychological, and logistical problems at the time of implementation (Driver, 1975; Kumar, et al., 2006; Wellington, 1981). Overall, the nature of problems is uniform, with minor accompanying regional variations. Students are still facing problems in connecting observation with inference (Carey, et al., 1989; Sampson, et al., 2015), and this situation is much prevalent in Indian schools. Therefore, a socio-culturally diverse country like India needs a learner-centric pedagogy to sustain its education system. That pedagogy should comprise the essence of a logical blend of a fresh approach with several other inquiry-based pedagogical approaches (Joy, 2014b; Kumar, et al., 2006). In this context, a pedagogy like Argument-Driven

Inquiry or ADI (Sampson, et al., 2010) seems indispensable because it has an inherently balanced approach targeting the overall development of students.

In recent days, several attempts are being made to write the textbooks with an inquiry-based approach, but ultimately the inclination remains towards problem-solving rather than creating inquisitiveness among the students (NCERT, n.d.). A balanced pedagogy like Argument-Driven Inquiry (ADI) is still not practised in Indian classrooms. No research data are found claiming prior use of ADI pedagogy in the Indian education system. For the first time, we are customising the ADI pedagogy according to the Indian context. Many alternations and modifications have been made in this process but without affecting the essence established by Sampson et al., (2010). This paper will delve into,

- introduction of ADI and its contextualisation.
- methodology for implementation of ADI in Indian classrooms.
- a small-scale deployment of the pedagogy.
- a forerunner initiative of a qualitative study of the effects of ADI based on that small-scale deployment in the real classroom of the Indian school.

Materials and Methods

Teaching-learning is a very complex and context-dependent process because of spatial and temporal differences in the condition of classrooms, the mindset of students and teachers, cultures and ethnicities, socio-economic structures, and the curricula too; so one needs to describe it adequately to develop the understanding (Kumar, et al., 2006). Hence, a descriptive or qualitative approach might be the best way to deliver a comprehensive idea of the overall situation (Berliner, 2007).

ADI and its Modification

The Argument-Driven Inquiry or ADI pedagogy was first developed and reported by Victor Sampson, et al. (Sampson, et al. 2010); later, National Science Teaching Association (NSTA) published many books (Sampson, et al. 2015) which they are using as guides towards implementing the pedagogy in classrooms of USA. According to Sampson et al., (2010), this pedagogy was planned "...to change the nature of a traditional laboratory instruction, so students have an opportunity to learn how to develop a method to generate data, to carry out an investigation, use data to answer a research question, write, and be more reflective as they work...". In addition, it creates an opportunity for students to take part in scientific argumentation and peer review process during a lab.

However, implementing the ADI pedagogy as it is, suggested by NSTA, might not befit the context of Indian classrooms because:

1. To date, there is very little provision for laboratory work in curricula of many Indian educational boards up to the 10th standard; even if it is there in some instances but rarely are brought into practice (Chandran, 2014; Sarangapani, 2014) due to several limitations discussed earlier in the introduction (Chandran, 2014; Cheney, et al., 2006; Joy, 2014a; Kumar, et al.,

2006; Muralidharan and Kremer, 2008; Sarangapani, 2014; Sarukkai, 2014).

2. There is a vast difference prevailing between rural and urban schools. Students from rural schools have different natural, social, economic, and infrastructural experiences than their urban counterparts.
3. Only one-third of secondary schools have an organised science laboratory facility in India (The National University of Educational Planning and Administration and Department of School Education and Literacy, Ministry of Human Resource Development Government of India, 2016).

Science education in most Indian secondary schools is limited to what the teacher preaches and explains in the classroom and demonstrates by performing experimental activities using very inexpensive tools. In comparison, almost 70 per cent of Indian secondary schools have computer facilities and a good percentage of qualified teachers (National University of Educational Planning and Administration and Department of School Education and Literacy, Ministry of Human Resource Development, Government of India, 2016). Considering these scenarios, at first, a few significant changes have been made to the basic structure of the pedagogy, such as:

- We conceptualised the foundation of ADI on logical analysis of theories and left scopes for designing experiments using inexpensive devices in several cases.
- Curriculum aligned probing questions were made by ensuring the following characteristics:
  1. Neither the questions nor the answers are addressed directly in their textbooks.
  2. The question must be devoid of any ambiguity.
  3. The question should have a concrete answer.
  4. The question should not lead to an erudite discussion.
  5. To solve those problems, students have to develop a strong analytical ability; they have to go through a series of logical analyses by concatenating several concepts that remain fragmented during a one-way classroom transaction.
- Further, those probing questions were presented in videos, graphics, or pictorial stories to the students. While doing so, our prime concern was to ensure the involvement of students. Therefore, the contents of videos and other forms of inputs were designed by aligning with their prior experiences and knowledge.
- Omitted the last stage or stage 7, namely "Double-Blind Group Peer Review," prescribed by NSTA at page number 13 of their guidebook by (Sampson, et al., 2015).

Intentional omission of that peer review stage was done as we were faced with the stark reality that the students, the infrastructure, and the curriculum of Indian schools are not in conformity with the spirit behind handling the same unbiasedly. However, apart from this, it was strongly felt that if we had tried to introduce something very complex or any idea alien to them at the very beginning, then that would have been received with a strong inhibition, and there were chances of students getting intimidated.

A complete outline of all the structural and instructional modifications that we made to ADI compared to the prescribed format by NSTA is presented in Fig. 1.

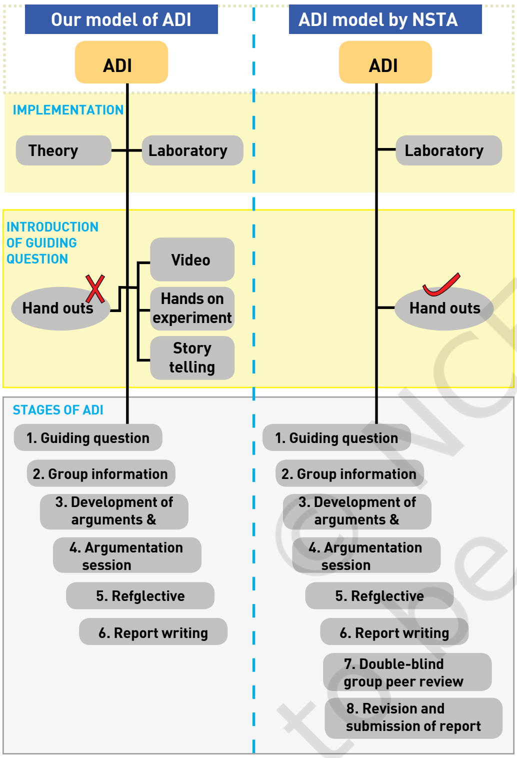

Fig. 1. Outline of the ADI model developed and implemented here (Left one) as compared to the ADI model prescribed by NSTA (Right one)

Participants

The study was carried out in two separate locations involving two separate groups of pupils belonging to two discrete categories. Each group comprised 48 students from six separate schools and a few trainee- teachers for overall monitoring of the process. Programmes were conducted under the overall guidance of experts from the research team. For the ease of further communication, we will denote the groups as 'SGp X' and 'SGp Y.' All the participants willingly took part in this experiment.

SGp X

Participants of this group belonged to urban or semi-urban areas. They were from families with a decent economic background, had private tutors, and had easy access to modern technologies and gadgets like television, computer, the internet, smartphones, etc. Moreover, they were blessed with well-educated predecessors in their families. In addition, pupils of this group belonged to different private schools with developed infrastructure, organised laboratories, and adequate teachers.

SGp Y

Participants of this group hailed from remote villages. They were from families with extremely weak economic backgrounds, and could not afford the facilities like private tutors and other educational materials. They had minimal access to modern technologies and gadgets like television, computer, the internet, smartphones, etc. They rarely had any educated elder members in their families; most were first-generation learners. Students of this group came from different public schools with nominal infrastructures, lacking organised laboratory facilities and adequate number of teachers.

Table 1
Selection criteria for experiment group SGp X and SGp Y

Groups / Selection Criteria	SGp X	SGp Y
Place of living	Urban or Semi-urban	Rural
Family income per year (INR)	≥200000	≤200000
If having private tutors at home ≥2	Yes	No
If 1st or 2nd generation learner	No	Yes
Having any of these two at home 1. Television, 2. Computer, 3. Smartphone	Yes	No
Having any access to at least 14 hrs of internet facility	Yes	No
Type of school	Private	Public
School has more than 20 teachers	Yes	No
Classrooms have audio-visual facilities like projector, etc.	Yes	No
School has well-organised laboratory facilities	Yes	No

Sampling of the student population

Forty-eight participants of each group were selected from Class IX. Initially, we prepared a list of schools from the district Paschim Medinipur, West Bengal, India. Schools were selected randomly from each of the categories. After contacting the schools, we randomly selected six willing schools for the study. Each school selected eight students of Class IX as participants. Then these 48 students, along with their respective class teachers, were invited to a venue selected for the study. After that, we again mixed them and randomly selected eight students to form one mixed population group. Thus, six groups of randomly selected populations were formed. Two separate studies were carried out in two separate locations for SGp X and SGp Y, respectively.

Tasks

At first, after psychological relaxation through a few fun activities, a video was played on the screen.

- The video contained many interesting facts about Photosynthesis and its relation with the existing living world; how these complex aerobic multicellular organisms evolved because of Photosynthesis.
- The visual had a subtle clue about the relationship between Photosynthesis, respiration, and growth.
- The video ended with one probing question or guiding question on the screen, "Between Photosynthesis and Respiration, which one is a comparatively slower process in a plant?" which they had to solve in groups.

Participants had to conclude, called the Claim, based on some evidence. Then, finally, they had to make an argumentation board putting their Claim, evidence, and justification of the evidence on it as prescribed by NSTA (Sampson, et al., 2015). The task was the same for both the SGp X and SGpY groups.

Interestingly, there was a strong initial tendency of school-wise polarisation among the students, but it gradually subsided. We considered this tendency shift to be the first step towards imbibing ADI pedagogy by the students.

Data Acquisition and Analyses

Studies with SGp X and SGp Y were conducted in two separate locations and dates. First, the whole event was video-recorded. Later, those videos were analysed to gather every piece of important information. Finally, analyses were done in terms of their interaction and responses.

The argumentation boards made by the groups were analysed. Each SGp X and SGp Y comprised six sub-groups, and each sub-group created an argumentation board. Evaluation of boards was done based on three criteria.

Criterion 1: Percentage of Clue-based evidence

We counted the total number of evidence (E) in each argumentation board, then counted the number of evidence established on the analytical base of the Clue (E_C), placed within the video, and converted the number in percentage (CE%).

$$CE\% = \frac{\sum E_C}{\sum E} x\,100 \ldots\ldots\ldots\ldots (1)$$

Criterion 2: Percentage of original evidence

Out of the total evidence (E), we identified those evidence representing an original thought and named those as Original Evidence (OE). This Original Evidence represented the ideas, which were neither a part of the video nor written in the books. Here we considered all the ideas that came from a unique analytical thought process, irrespective of themselves being conceptually correct, partially correct, or incorrect. We did so to understand their internal drive to find a unique solution to a problem. The reason behind the correctness of the idea might have depended on several factors, and we tried to address a few of these factors of interest with the qualitative approach later, but here Original Evidence (OE) had been converted to percentage using the following formula:

$$OE = \sum E - \sum E_C$$

$$OE\% = \frac{\sum OE}{\sum E} x\,100 \ldots\ldots\ldots\ldots (2)$$

Criterion 3: Graphical presentation of the idea (G_i)

The third criterion measured their ability to represent an idea or complex thought intuitively and simplified with graphs or diagrams. There we took a 3-point scale where one indicates "Bad or No Graphics," two indicates "Moderate," and three indicates "Good." That means each group could have a score (G_S) out of 3 or maximum (G_{max}) based on this 3-point scale. Finally, the score was converted into a percentage (G_i%) using the following formula:

$$G_i\% = \frac{\sum G_S}{\sum G_{\max}} x\,100 \ldots\ldots\ldots\ldots (3)$$

Results and Discussion

Focus areas of the experiment

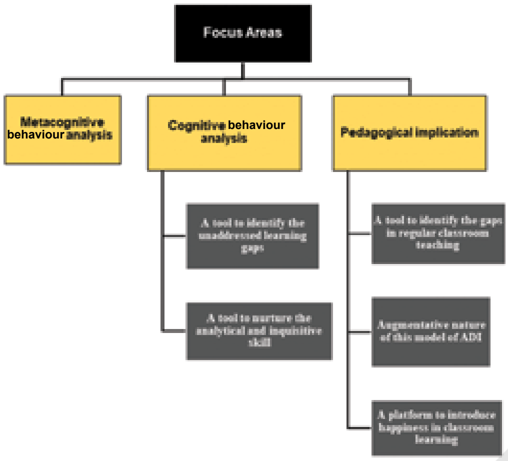

Fig. 2. Focus area of the study

Metacognitive behaviour analysis

The scope and practice of group activities are very limited in regular classrooms of Indian schools. Those are mostly practised in the playground or physical education classes but rarely in science classes, so the students are not familiar with the system (Chandran, 2014; Sarangapani, 2014). From the video content analysis, it was clear that students initially felt very uneasy in SGp X and SGp Y. Initially, they started working individually or in tiny groups within the activity group of eight pupils. With time they got habituated and started working as a single complete group. During the practice of ADI pedagogy, over time, both the groups were found to open up and get involved in group activities overcoming all the intrinsic impediments. This could be sensed from one of the participant's feedback items (transcribed from Online Resource 1OR_Feedback: https://doi.org/10.6084/m9.figshare.9995828)

"At first, we were hesitating as we were from different schools. We were kind of an introvert and not mingling with one another, but when we started talking, we saw that pupils have different ideas and concepts on the same topic."

Schools are where students spend most of their time in a day— so achieving our target of equity and equality in education (Kumar, et al., 2006; National Council of Educational Research and Training, 2005; National University of Educational Planning and Administration and Department of School Education and Literacy, Ministry of Human Resource Development, Government of India, 2016) we should adopt such a pedagogy in the classrooms which are not only effective in developing optimum scientific skills and aptitude but also efficient enough to ensure the overall development of next-generation learners of India. The study showed the effectiveness of ADI pedagogy in this context, though on a very small scale. During their feedback, participants from the group SGp X said (transcribed from Online Resource 1OR_Feedback: https://doi.org/10.6084/m9.figshare.9995828)

Participant 1 : "Here, working in the group increased our team spirit. It is very new to us; we did not do this before."

Participant 2 : "I not only learned Photosynthesis or respiration, but I have learned to bring scientific temper within me. I have also learned to write scientifically and to read scientifically.".

Cognitive behaviour analysis

A tool to identify the unaddressed learning gaps

Claims made by all the groups of both SGp X and SGp Y were correct, and so we analysed every evidence (see Fig. 3; Fig. 4; Fig. 5; and Online Resource 2OR_ADI_Boards: https://doi.org/10.6084/m9.figshare.12054090) put in the argumentation board by student groups and identified a few statements which were carrying signs of unique approaches towards the solution to the problem. We marked every piece of evidence with a unique approach, though that may be conceptually right or wrong. The key reason behind the consideration was to gauge their internal drive for taking a unique approach toward solving a problem. As an exhibit, the excerpt presented by Group 2 of SGp X is mentioned below (see Fig. 3)

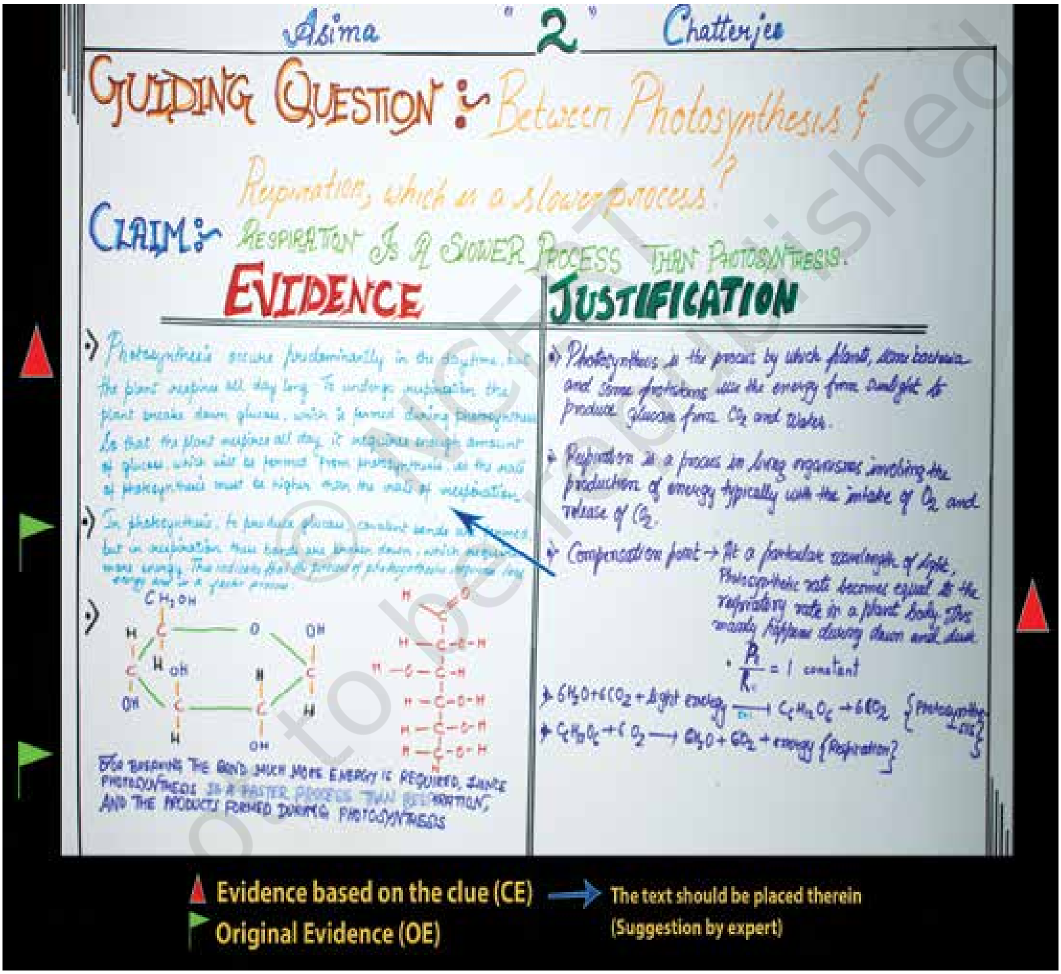

Fig. 3. Argumentation board made by Group 2 of SGp X.
(The board has been annotated, and the annotation legend is on the board)

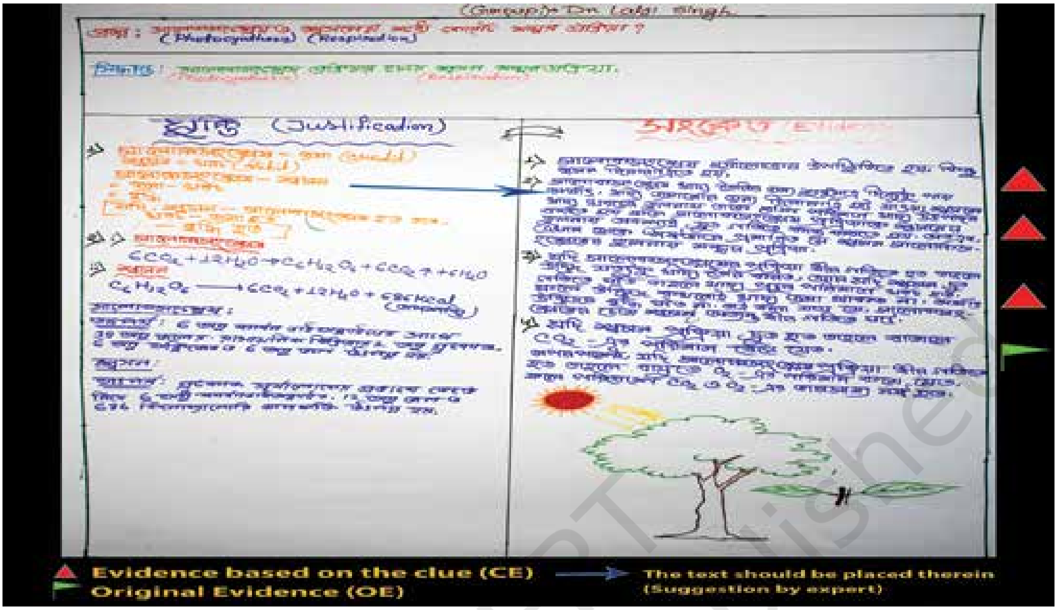

Fig. 4. Argumentation board made by Group 6 of SGp Y. (The board is written in the Bengali language as participants were from Bengali medium schools. The board has been annotated, and the annotation legend is on the board)

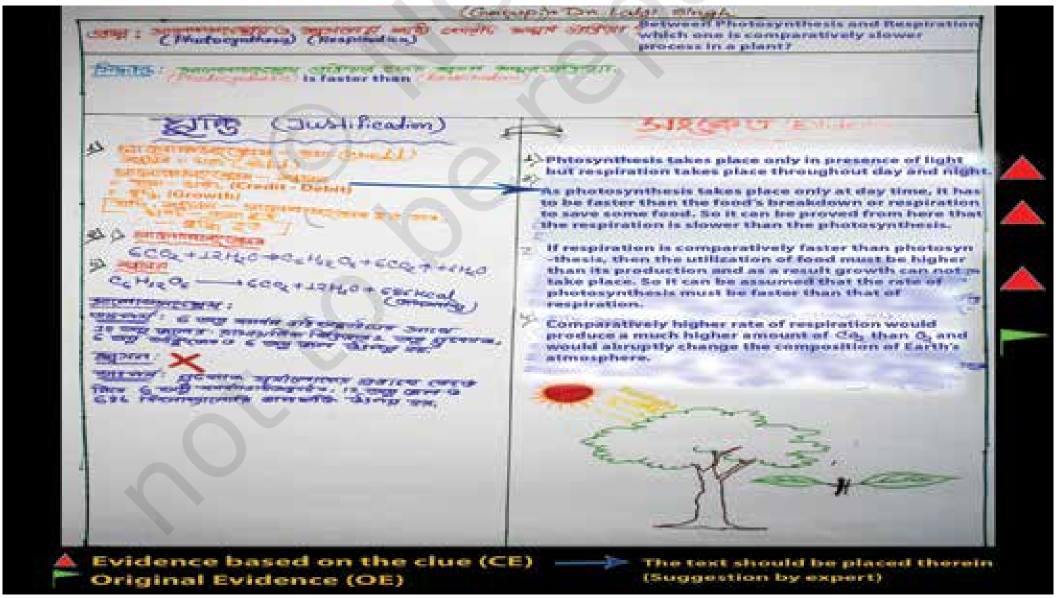

Fig. 5. Transcribed argumentation board made by Group 6 of SGp Y. This has been transcribed in English as the original board was made in Bengali. The transcript has been edited using Adobe Photoshop CS4 (The original board has been cited as Fig. 4.)

"In Photosynthesis, covalent bonds are formed to produce glucose, but in respiration, these bonds are broken down, which requires more energy. This indicates that the process of Photosynthesis requires less energy and is a faster process." (Sic)

This statement is evidence of their endeavour to keep no stone unturned within the limitations of their reach and exert maximum effort to analyse all the pieces of information they had gathered. Similarly, the statement has another exciting story to tell. The group had gone through 'Bonds and their nature' in the classroom, and they tried to use that knowledge to solve the problem. Nevertheless, it is evident from the statement that they had wrong concepts about the chemical reaction and interaction of bonds; otherwise, they could have understood that breaking of bond releases nearly the same amount of energy trapped during its formation. They also did not have a rational idea about the processes of making and breaking glucose in plants. These conceptual gaps remained unidentified and unaddressed, and might have continued to do so until they went through the process of ADI during this study. So, this pedagogy could be used frequently in classrooms as a formative assessment to identify the gaps of teaching-learning. According to one participant (transcribed from Online Resource 1OR_Feedback: https://doi.org/10.6084/m9.figshare.9995828):

"We had lots of misconceptions which cleared after exchanging our thoughts with other group members and participants, and getting proper criticism from them." (Sic).

Again, this pedagogy could fill up those gaps. To do so, the teachers should move strategically with an element of creativity and modification of the system, as we know that erroneous learning could be turned into beneficial learning if followed by corrective feedback. For example, according to (Metcalfe 2017), the error committed with high confidence could be corrected more readily, and the lesson could be more permanent than low-confidence errors. Likewise, we did in the reflective discussion session.

First, the expert asked: "What is being formed during Photosynthesis?"

Participants: "Glucose"

Expert: "What is being broken down in respiration to produce energy?"

Participants: "Glucose"

Expert: "That means both are the same, so the same bonds are being produced during Photosynthesis and are being broken down during respiration. Do you agree?"

Participants: "Yes, we do."

Expert: "How can you assume that the same product carrying the same bond will require a different amount of energy and time during formation and breaking down through reverse reactions? Is it possible? What do you think?"

Participants: "No, it is not possible."

Expert: "Now, do you agree with this statement of yours - 'in Photosynthesis, to produce glucose, covalent bonds are formed, but in respiration, these bonds are broken down, which requires more energy. This shows that the process of Photosynthesis requires less energy and is a faster process." (Sic)

Participants: "No, that was a misconception."

Not only could the students benefit from it, but the teachers would also gain valuable information from errors, and error tolerance encourages students to engage in exploratory activities.

An essential lesson of ADI is that the students should not be discouraged from committing errors. On the contrary, they should realise that such errors are not mistakes, not to speak of blunders!

A tool to nurture the analytical and inquisitive skill

Curiosity is the ultimate drive behind every sort of knowledge. Curiosity generates question, and question generates knowledge. However, unfortunately, students are losing their habit of questioning. The practice of traditional one-way classroom transactions makes them mere passive listeners (Sarangapani, 2014). This study showed that ADI pedagogy could transform the current scenario of the classroom by transforming the students from passive listeners to active question raisers, and the fact was also admitted in her feedback by a teacher who took part in the study (see Online Resource 1OR_Feedback: https://doi.org/10.6084/m9.figshare.9995828). Students made several errors in due course of practising ADI pedagogy during the study. By way of committing errors, they got a stimulus to learn more; and as they learned more, they gathered more experiences, got more raw materials to enhance their analytical ability. With deep understanding, when they tried to analyse, they came up with lots of queries, which started a healthy cyclic reaction. In our study, we came across an interesting statement put by Group 4 of SGp X on the argumentation board as evidence, and it was like (see Online Resource 3OR_ADI_Board: https://doi.org/10.6084m9.figshare.12064314):"Respiration has greater numbers of steps, so phases are longer and slower than Photosynthesis,"

At the Reflective Discussion session, we performed an elementary set of low-cost experiments on displacement reaction, using (a) $CuSO_4$ solution and iron nail (b) $AgNO_3$ (aq) and NaCl (aq), to show that not all the chemical reactions take an equal amount of time to complete. Therefore, the overall reaction time of a complex biochemical process does not depend on the number of steps it involves. We also demonstrated that a reaction does not take place at the same speed in-vivo and in-vitro with the help of another simple set of experiments of Oxygen Evolution Reaction () (Ghosh and Rahaman, 2018). OER was demonstrated through in-vitro electrolysis of water and in-vivo photolysis of water within *Hydrilla sp*., (detail description of all the previous experiment set up could be found here https://doi.org/10.6084/m9.figshare.17427407.v1). Consequently, a question came from their end, and the question was, "What are the factors affecting this reaction speed in-vivo?" That is how ADI did its job. To get rid of the usual lecture method of teaching-learning, moreover making science classrooms interactive and vibrant space, schools need a pedagogy like Argument-Driven Inquiry as echoed in the feedback of participants (transcribed from Online Resource 1OR_Feedback: https://doi.org/10.6084/m9.figshare.9995828).

"We get to learn how to reach the core of a topic. In schools, we study only theories in a straightforward way; that is how our teachers taught but did not get the opportunity to analyse and connect,".....Participant: 3.

"I learned here how to ask questions and the importance of questioning. Previously I did not ask questions, or even if I asked, either the question or my way of asking was wrong. So I repent if I would have asked questions that came in my mind on those days, I would have learned more,"....Participant: 4.

Pedagogical implication

A tool to identify the gaps in regular classroom teaching

Before this experiment, their respective class teachers in their schools taught students topics like Photosynthesis and Respiration as usual. After analysing the data obtained from the experiment, we found that ADI could be used to improve the quality of classroom teaching by applying it as a tool to find the gaps therein. In the argumentation boards of the groups SGp X and SGp Y, only 33.33 and 29.17 per cent of evidence respectively represented original evidence, and the rest of the part was based on the clue shown within the video of the probing question. Therefore, from Table 2, one could understand that students had a strong dependency on what they have seen or on the information that has been supplied to them, but they could not carry out critical analysis based on those pieces of information, and a similar view could be found in Joy (2014b).

Table 2
Quantitative analysis of the Argumentation Boards made by different groups of SGp X and SGp Y

Name of Grouwps /Subgroups	SGp X					SGp Y				
	Evidence based on the clue (CE)	Original evidence (OE)	Total Evidence (E)	Graphical presentation of idea (Gi)		Evidence based on the clue (CE)	Original evidence (OE)	Total evidence (E)	Graphical presentation of idea (Gi)	
				Gs	Gmax				Gs	Gmax
Group 1	05	00	05	01	03	04	00	04	01	03
Group 2	02	02	04	01	03	03	03	06	03	03
Group 3	02	02	04	03	03	05	00	05	01	03
Group 4	03	01	04	02	03	03	01	04	02	03
Group 5	01	03	04	03	03	01	03	04	01	03
Group 6	05	00	05	01	03	03	01	04	01	03
Total (∑)	18	08	26	11	18	19	08	27	09	18
Average ± SD	3 ±1.67	1.33 ±1.21	4.33 ±0.52	1.83 ±0.98	3.00 ±0.00	3.16 ±1.33	1.33 ±1.36	4.50 ±0.84	1.50 ±0.84	3.00 ±0.00
Percentage (%)	69.23	30.77	100	61.11		70.37	29.63	100	50	

With such analysis, teachers could identify the gaps in their regular teaching, and work on developing analytical ability and critical thinking among the students. In addition, the score of 'Graphical presentation of the idea' (Table 2) could help teachers understand the usability of the concept map and other forms of graphical presentation in the classroom. Unfortunately, the current curriculum structure and the Indian schools' infrastructure have very little space for regular implementation of the Argument-Driven Inquiry pedagogy. Considering the above discussion, it can be suggested that ADI implementation can be considered intermittently for formative assessment in schools. One of the school teachers, who took part in this experimental process as a trainee, expressed a similar thought in his feedback (transcribed from Online Resource 1OR_Feedback: https://doi.org/10.6084/m9.figshare.9995828):

"We taught the meaning of Photosynthesis and the process, and we also taught respiration as another separate process in schools. However, I never thought to ask or think on such a thing that between Photosynthesis and respiration which one is slower or faster."

Augmentative nature of this model of ADI

According to the report published by the National University of Educational Planning and Administration in 2015 (National University of Educational Planning and Administration and Department of School Education and Literacy, Ministry of Human Resource Development, Government of India, 2016), only 33.89, 33.64, and 32.02 per cent of Indian higher secondary (10+2) schools have a separate room for the laboratory of physics, chemistry, and biology respectively, and the scenario must be worse in secondary schools (up to Class X) because there is minimal provision for laboratory work in the secondary curriculum throughout the nation (Joy, 2014b; Sarangapani, 2014). Theoretical study, logical analysis, and some low-cost classroom experiments are the only means for studying science subjects in India, at least at the stage of secondary education. So, sticking with the current curriculum framework, the ADI pedagogy cannot be implemented to improve the quality of experimental science in laboratories as practised in the USA (Sampson et al., 2010, 2015). Therefore, this model of ADI was designed for theory classes and from the above discussions that seemed befitting to the Indian context. Although this pedagogy could not replace the ongoing teaching process because initially, teachers have to teach the topics with the process they are used to, and then they could apply the ADI intermittently to strengthen the teaching-learning process. The teacher concerned, according to the necessity and demand of the situation, could determine the frequency of using the ADI.

A platform to introduce happiness in classroom learning

The most precious outcome of our experiment was the expression of happiness on students' faces. During analysis, the videos showed reflections of surging enthusiasm and smiling faces in every frame, and that is one of the most crucial parts amidst the crowd of tangible outcomes (Online Resources 4OR_SGp X: https://doi.org/10.6084/m9.figshare.9995918 and 5OR_SGp Y: https://doi.org/10.6084/m9.figshare.9995921). Another teacher, who took part as a trainee in one of these experimental workshops, shared one of his significant experiences after the first day of the workshop in his feedback (transcribed from Online Resource 1OR_Feedback: https://doi.org/10.6084/m9.figshare.9995828).

"When we were returning from here to our places, students were asking me eagerly, sir, when are you going to start this in our classroom?"

In every learner-centric model of education, the happiness of learners is the ultimate word. Any pedagogy or model of instruction cannot be effective if it fails to attract the learners so in this respect, the pilot run of the model of Argument-Driven Inquiry pedagogy, which has been designed for Indian schools, could be claimed as fruitful.

Conclusion

In this experiment, ADI pedagogy was redesigned to match the context of the Indian education system, and pilot runs were conducted to experience its effectiveness. Two groups of students, one from remote villages and another from urban areas, were selected to study the impact of this pedagogy on the teaching-learning process. The study found, albeit the vast difference in their experience, mindset, and institutional infrastructure, that both groups have similar gaps in understanding science. This can be attributed to the fact that they were being taught mainly through the exact traditional information-centred teaching mechanism.

This ADI pedagogy was observed to bring some visible changes within their behaviour, such as they started to inquire spontaneously and analyse critically, they gradually opened up and started interacting with each other. They were observed to collaborate to find solutions through group activity. ADI was found to be effective in identifying gaps in learning and teaching. Above all, the pedagogy was observed to bring spontaneous involvement and happiness in the teaching-learning environment. Although the ADI pedagogy cannot replace the traditional teaching system in India's science classrooms, it can be used effectively to augment the current system.

However, we have a long way to go before implementing it at every school in India. The prominent impediments in this journey are an intrinsic inhibition within the teachers and school administrators to accept something new, lack of space and time for ADI within the current curricula, lack of infrastructural support in rural schools, and most importantly, the lack of awareness among the parents of the students. Based on the outcome of the Experimental Workshop, which *inter alia*, generated tremendous enthusiasm among the students and the teachers, our current strategy would be to strike a balance between ADI and the existing teaching-learning process in the schools.

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Declarations

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Conflicts of interest

On behalf of all authors, the corresponding author states that there is no conflict of interest.

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