SCIENTIFIC ARGUMENTATION – A THEORETICAL FRAMEWORK

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Science is a subject that involves the construction of theories that explain phenomena that are open to challenge and refutation, which is done by regular observation, framing and questioning hypothesis, experimentation, collecting data, etc. All these processes make the subject practical and instill curiosity among learners. scientific concepts are meant to be questioned to arrive at an answer or explain the why, how, what, and what if. Thus, it is said that science can be better understood if it proceeds through dispute, conflict, and argumentation. To bring out the essence of scientific discussion in a classroom or to make students more involved in the classroom discussion, argumentation in science is essential. Cavagnetto, R. (2010) pointed out that students' participation in argument develops communication skills, critical thinking, an understanding of the culture, practice of science, and scientific literacy. This paper has tried to bring out how crucial scientific argumentation is for reasoning and thinking, how we can link between evidence and claim, and why students and teachers need to be more involved with scientific argumentation. One need to understand that there is a vast difference between typical argumentation and scientific argumentation. Also, our discussion has further emphasised understanding Toulmin's definition of argument from a theoretical perspective and as a methodological tool for analyzing an argument, also known as Toulmin's Argument Pattern (TAP). In this theory, he has discussed various components of an argument and how it helps students evaluate the validity and strength of arguments in science. The paper has even focused on the teaching strategies for carrying out argumentation, as discussed by Simon, Erduran, and Osborne (2006). With this, it can be concluded that still many teachers are unaware of this method of argumentation and can be brought to them by collective workshops. Even in the in-service teaching programmes, an attitude towards scientific argumentation can be introduced.

Keywords: Scientific Argumentation, Toulmin's Argument Pattern (TAP), scientific literacy.

Introduction

Science is a discipline that fosters curiosity and creativity in a child. This subject needs a systematic approach, starting from observing phenomena and collecting data, formulating hypotheses, experimenting, and constructing theories. To learn science better, one needs to proceed through dispute, conflict, and argumentation (Latour and Woolgar, 1986). Argumentation has been of increasing interest in science education as a means of actively involving students in science and, thereby, as a means of promoting their learning (Duschl and Osborne, 2002; Kim, M., and Roth, W.M. 2014). Argumentation is not a new area. Some great philosophers, such as Plato and Aristotle, have been engaged in argumentation (Erduran, S., Ardac, D. and Yakmaci, B., 2006).

Argumentation in science solely means giving justifications and pieces of evidence for a claim. It is an activity that draws a quality conclusion based on proof and justification and explains the relation between a claim and proof (Driver, et al., 2000; Dusch, et al., 2007; Chin and Osborne, 2010). However, it turns out that many students are unaware of

how to proceed in scientific argumentation, or rather, we can say they fail to give evidence and justification to some of their claims about the natural world (Erduran, S., Ardac, D. and Yakmaci, B., 2006). For instance, if we take the question, "Does the sun really set and rise?" Few students could answer this question, but some have undertaken the statement as a given fact without knowing the actual cause behind the phenomena. This fact has to be questioned; they have to be argued systematically for a proper understanding. Thus, it was observed that argumentation improved students 'conceptual understanding, thinking critically, helping them to make an informed decision, and enabling them to work in a scientist's way (Faize, Husain and Nisar, 2017). Gradually, the demand for argumentation increased in science, and we started working with different dimensions of argumentation. In this paper, to further understand the depth of argumentation, we will discuss Toulmin's Argumentation Pattern (TAP) and its importance.

It has been analysed that students' participation in argument develops communication skills, metacognitive awareness, critical thinking, and scientific literacy (Cavegnetto, A., 2010). So, here we have tried to discuss further why an argument is necessary, how it develops different skills in students, and how it fosters scientific temper? This paper has even focused on how scientific Inquiry differs from scientific argumentation.

Toulmin's Argumentation Pattern helped in modelling a structured argumentation, and it had some drawbacks too. First, Toulmin's component is bleak, and sometimes it is not easy to distinguish the components from one another, such as data, warrant, and backing (Erdurn, et al. 2004; Faize, F., Husain, W., and Nisar, F., 2017). And second, there were no proper tools to analyse the quality of the argument.

In conclusion, the paper discusses how Toulmin's work has been used to develop a theoretical framework on the argument, how this argument can encourage students towards scientific literacy, and what strategies can enhance the argumentation process in scientific discourse.

Objectives

1. To critically analyse Toulmin's Argumentation Pattern.
2. To find out the role of scientific argumentation in developing scientific temper.

Research Questions

1. What is the framework of Toulmin's Argumentation Pattern?
2. What is the role of scientific argumentation in developing scientific temper?

Methods and Procedure

In this paper, we have used the approach of document analysis to understand the importance of scientific argumentation in a classroom. According to Bowen (2009), "In Document Analysis, the documents—both printed and electronic material are evaluated and reviewed in a systematic procedure." Here, the document containing both text and images is examined and interpreted to elicit meaning and understanding. Documents can take different forms like advertisements, minutes of the meeting; background papers;

books and papers; news and television; newspapers; books and journals in libraries, etc. The preferred documents undergo an analytic procedure that includes finding, synthesizing, comprehending the data present in the document.

As pointed by Bowen (2009),

"Document analysis involves skimming (superficial examination), reading (thorough examination), and interpretation."

In document analysis, the sequential analysis process combines elements of content analysis and thematic analysis. Content analysis is the process where information is put into categories related to the central questions of the research, whereas in thematic analysis, a form of pattern is recognised within the data, with emerging themes, and thus further categorised for analysis (Fereday and Muir-Cochrane, 2006; Bowen, 2009).

This paper has focussed on the work of Toulmin's Argumentation Pattern from the document: by The Uses of Argument. "Toulmin, S. (1958)." The analysis helped us understand the model and the proper structure in argumentation. The paper has discussed the role of different components like data, quantifiers, warrant, backing, claim, and rebuttals and their role in scientific argumentation. In addition to this, other documents like 'The Argument to Foster Scientific Literacy: A Review of Argument Interventions in K-12 Science Contexts' (Cavagnetto, A.R., 2010); 'Learning to Teach Argumentation: Research and Development in the Science Classroom' (Simon, S., Erdnran, S., and Osborne, J., 2006) and 'Using Toulmin's Argument Pattern in the Evaluation of Argumentation in School Science' (Simon, S., 2008) were analyzed that further us to interpret the original document by Toulmin (1958), as most of these papers researched and reviewed Toulmin's work and upon further scrutiny, they had developed a scheme where argumentation was assessed in terms of level. Also, the six elements of TAP for constructing an argument were simplified to five elements. Important excerpts and concepts were taken from the documents, and these original and reviewed papers were analyzed to produce empirical knowledge; through this, an understanding of the concept was developed.

Analysis and Discussion

To critically analyse Toulmin's argumentation pattern

Meaning of Argumentation

Argumentation in science education is quite different from how it is used daily. It is not a 'heated exchange' of opinions and emotions between two rivals to defeat them (Duschi, Scweingruber, and Shouse, 2007; Scientific argumentation, 2013; Faize, F., Husain, W. and Nisar, F., 2017). Instead, it is a systematic approach to find the relation between ideas and shreds of evidence. These include evaluation and validation before reaching any conclusion. Furthermore, the argument in education follows a particular structure involving certain components (Toulmin, 1958; Faize, F., Husain, W. and Nisar, F., 2017). This makes argumentation different from casual dialogues, which are less certain, but argumentation welcomes different opinions from different groups giving justifications for their claims Osborne and Patterson, 2011). In a way, we can say that the process of argumentation undergoes a

series of criticism, explanation, evidence, and refutation. First, however, one needs to understand that there is a slight difference between argument and argumentation. Argument refers to the subject of claims, data, warrants, and backings that contribute to the content of the argument, whereas argumentation refers to the process of assembling these components (Simon, Erduran and Osborne, 2006).

Toulmin's Theoretical Perspective on Argumentation

To involve in a proper argumentation, one should follow a proper structure. There had been many researchers on the same. However, here, among all, we tried to discuss the idea given by Toulmin (1958). From Toulmin's perspective, arguments have specific components, which include a claim, data that supports the claim, warrants that provide a link between the data and the claim, backings that strengthen the warrants, and rebuttals indicate the situations under which claim would not be valid (Simon, S.,2008). This interconnection between argument components helps to understand the meaning of the argument. The figure below shows Toulmin's Argument Pattern (Toulmin, 1958) and further modified by from Simon, S. (2008).

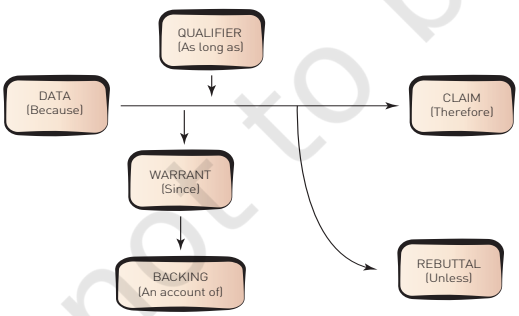

Fig. 1 Toulmin's Argument Pattern

Table 1

Definitions of Different Terms related to Argumentation

Terms	Definitions
Claims	The assertion about what exists or values that people hold.
Data	Statements that are used as evidence to support the claim.
Warrants	Statements that explain the relationship of the data to the claim.
Qualifiers	Special conditions under which the claim holds.
Backings	Underlying assumptions that are often not made explicit.
Rebuttals	Statements contradict either the data, warrant, backing, or qualifier of an argument.

The terms given in Table 1 are according to Toulmin (1958) and later redefined by Simon, S. (2008). Further research was done on Toulmin's definition by Osborne, Erduran, and Simon as a framework for analysing the components of arguments occurring in the classroom discourse and hence the quality of education (Erduran, Simon, and Osborne, 2004; Osborne, Erduran and Simon, 2004a; Simon, Erduran and Osborne, 2006). Upon deep analysis, it was found that the more elements of TAP were present in the dialogue, the better the quality of argumentation and vice-versa. Let us try to understand Toulmin's Argument pattern model with an example given below.

Erduran, Osborne, and Simon generated a scheme where argumentation was assessed in terms of levels, which depicted the quality of opposition or rebuttals in the students' small group discussions (Erduran, Simon, and Osborne, 2004; Osborne, Erduran and Simon, 2004).

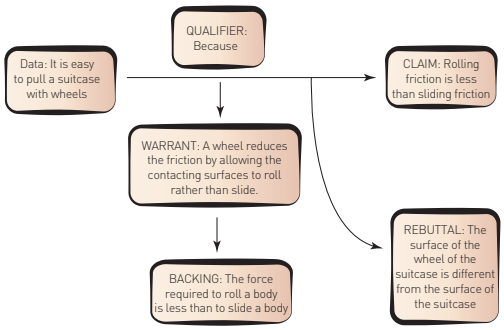

Fig. 2 Toulmin's Argument Pattern with an example

It is seen that the arguments with a rebuttal increase the strength of the argument. We can define arguments in two ways: (i) Low-level arguments included counter-arguments that were unrelated, and (ii) Higher-level arguments included rebuttals (Simon, S., 2008).

The analytical framework used for assessing the quality of argumentation is shown in Table 2 (from Erduran, et al. 2004 p. 928; Simon, S., 2008).

Table 2

Analytical Framework Used for Assessing the Quality of Argumentation

Level 1	Argumentation consists of arguments that are straightforward claims versus a counter-claim or a claim versus a claim.
Level 2	Arguments consist of a claim versus a claim with either data, warrant, or backings but do not contain any rebuttals.
Level 3	Argumentation has arguments with a series of claims or counter-claims with either data, warrants, or backings with the occasional weak rebuttal.
Level 4	Argumentation shows arguments with a claim with an identifiable rebuttal. Such an argument may have several claims and counter-claims as well.
Level 5	Argumentation displays an extended argument with more than one rebuttal.

These levels ensure the complexity of an argument. If a student's argument consists of more rebuttals, it implies that the student has critical thinking skills and comprehends things better.

In Table 1, we observed that TAP has six elements, but in the recent research, it has been simplified to five elements (Erduran, et al., 2004; Hanri, C, Arshad, M. and Surif, J., 2017), they are claim, data, warrant, backing, and rebuttal. In the present research, TAP was further modified. First, the warrant, qualifier, and backing are grouped based on their common value (Erduran, et al., 2004; Hanri, C, Arshad, M. Y. and Surif, J., 2017), which in justification one new element is added, i.e., refutation. A refutation is required if a claim is questionable or controversial. The next important thing is how these TAP can be used in a classroom discourse by students and teachers.

The Role of Scientific Argumentation in Developing Scientific Temper

Science as a subject demands a constructive approach and critical thinking. It requires the ability to accurately and effectively interpret and construct science-based ideas (Cavagnetto, A., 2010). Therefore, scientific temper develops overall skills of a human-like ability to understand the cultural aspect of science, metacognitive processes, communication skills, and reasoning skills (Cavagnetto, A., 2010). These skills help learners to understand scientific concepts better. However, in this scientific field, we need to know the importance of argumentation. There are different forms of argumentation. However, all form does not foster a scientific temper; for a lawyer, the argument is to win the case. However,

scientists use arguments to vet ideas to work towards a common goal – advancing scientific knowledge (Toulmin, Rieke, and Janik, 1984; Cavagnetto, A. 2010).

There are many research on whether argument interventions in school science foster scientific temper. This paper has tried to summarise all previous research on how scientific argumentation fosters scientific temper or literacy.

We need to emphasise why argumentation is necessary for students after all. First, argumentation makes the learning meaningful, which means it helps learners connect with the scientific nature, and now, they know the reason behind a particular phenomenon, which further helps them get more involved. Second, it develops communication skills; as we talk about communication, we emphasise the role of language. Third, it is fundamental because it drives the in-depth and epistemic nature of science and captures the culture of science (Cavagnetto, A., 2010). Fourth, argumentation somehow prompts students' critical thinking and reasoning. It is seen that very few people understand the structure of argumentation. Primarily, students lack the very idea of argumentation. As a result, it becomes difficult to identify a warrant and backing. According to Sadler (2004), it was found that students struggled with argument construction and consideration of evidence that contradicted their initial views. They go for more direct evidence for any claim given. Lack of an argument has led to the conception of sciences as a collection of static facts about nature and perception of Science as a secular religion (Driver, et al., 2000; Cavagnetto, 2010). To foster argumentation, students must understand the importance of social interaction and how cultural factors influence science (Kuhn, T., 1962; Cavagnetto, 2010).

According to Cavagnetto (2010), it has been often noticed that, in school science, the facts or the right answers have been emphasised to the exclusion of scientific practice and thinking. Students are reinforced in the classroom to give correct answers without knowing why it has to be the correct answer. As a result, students lack the motivation or have minimal opportunity to share findings, interpretations, or ideas. To encourage scientific temper, the perspectives of the nature of science must change.

Ford (2008) believes that to understand science, it is necessary to understand the nature of science, its social and cultural elements. Further, he defined certain things that showed the interaction between material and social aspects of science. It explained, (a) getting nature to "speak," which means helping students to identify questions for exploration, designing appropriate ways to answer those questions, conduct investigations, and communicate these processes to others, and (b) "portraying nature's voice," which includes interpretation of data and subsequently construction of evidence-based explanations. To ensure scientific temper among children, it is necessary to understand what argumentation in science means and how it can be framed and practised within the classroom.

Argumentation can be promoted within the classroom through appropriate activities and pedagogical strategies. Adopting any new approach that promotes the use of argument would require a shift in the nature of the discourse in science lessons (Simon, Erduran,

and Osborne, 2006). To make argumentation more effective in the classroom, the teacher subsequently plays a significant part. It has to be ensured that certain strategies are followed in the classroom to help learners identify the components of arguments, construct meaningful evidence, and enhance critical thinking among them.

Teaching Strategies and Role of Teachers

In order to help learners to be a part of scientific argumentation, teachers must follow up specific teaching strategies, which will help both the learners and teachers to move forward in a meaningful argumentation. The teaching strategy, as discussed by Erduran, et al. (2006), must focus on how the teachers (a) structure the task, (b) use group discussions, (c) question for evidence and justifications, (d) model argument, (e) use presentations and peer review, (f) establish the norms of argumentation, and (g) provide feedback during group discussion. If practised, these strategies might help teachers and learners take part in the argumentation process and construct meaningful arguments. Over that, the teachers and the learners have an essential part to play. According to Simon, Erduran, and Osborne (2006), along with the strategies mentioned above, a few more points are necessary for this process, i.e. (i) the learner needs to work in groups and listen to each other articulating their ideas in the discourse. In addition, the teacher must make sure that learners are paying attention to what others are speaking; (ii) the teacher must attempt to help learners understand what arguments mean. This can be done by defining an argument or exemplifying it; (iii) encouraging learners to take up a position individually or as a group. This helps them to be more determined for what they are arguing for and thus, will help them to justify themselves; (iv) to encourage learners to provide evidence for any justification; (v) learners must be engaged to construct arguments, either by summing up in sheets or through presentations; (vi) teacher must ensure evaluating the evidence, as it makes a string argument; (vii) to encourage counter arguing and debating, as it will help learners talk out about their feelings on the arguments; and (viii) help learners reflect upon the argument process.

However, there are certain specific roles that a teacher must take up to encourage the idea of argumentation, as it is seen that teachers' passive explanation can decline the very idea of argumentation. Argumentation is avoided due to teachers' limited knowledge and sometimes, focussing on correct answers. In many parts of our country, teachers are still unaware of scientific argumentation and its elements. Teachers contribute a lot to this society; thus, they have to put in some effort. To achieve this process, teachers can help learners polish and improve argumentation skills (Hanri, Arshad and Suri, 2017); teachers can help students improve their higher-order thinking skills (Hanri, Arshad and Suri, 2017).

It has also been noticed that language plays a central role in scientific practice – the reason is, it requires and enhances abilities, such as metacognition and critical reasoning. Language drives the epistemic nature of science and captures the culture of science. It can be noticed that science is othing without texts, various modes of representation, and talk. Among all, argument plays an essential aspect in the language practices of science (Cavagnetto, 2010).

Conclusion

In this paper, we have tried to analyse the meaning of argumentation and how the argument is different from argumentation. While emphasising argumentation, we have tried to bring the theoretical perspective on the argument given by Toulmin by using its different components, also called Toulmin's Argument Pattern (TAP). This framework provides a means of modelling arguments for students by focussing on components and links that can emphasize the use of evidence (Simon, S., 2008). With its use of different components, one can assess the complexity of the argument, i.e., more the components, the argument is considered to be stronger. However, it has its limitations, like, identifying the components can be misleading, and there is no proper way to evaluate the quality of the argument.

Further, it has discussed how argumentation can foster scientific temper. As per the discussion above, argumentation helps learners think critically, enhances higher-order thinking skills and communication, and a proper approach to solving problems. These skills make learners more involved to understand the nature of science, or we can say, these are the skills, what the subject demands. Moreover, along with the learners, the teachers' role is crucial. Teachers must ensure that class is not passive and put more effort into making it student-centred, where learners construct their arguments.

Furthermore, teachers should follow strategies to help students be involved in scientific explanations and create a scientific environment. Lastly, it was seen, among all, that language also plays an important role. Because, without it, we cannot represent science.

To conclude, for the upcoming research on argumentation, we need to promote the very idea of argumentation within the classroom and its effect on the learners. Because learning science is not about memorizing facts but understanding the underlying depth, thus teacher's awareness must be created on the same.
Teachers must undergo professional development courses to understand it better and train the learners. Models must be created to simplify the components further, and a proper tool must be developed to assess the quality of arguments. Further, the argumentation course in the pre-service course would help budding teachers for the coming generation and help create a scientific environment.

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