Peer-reviewed article

The effect of socio-scientific issue (SSI) based discussion: A student-centred approach to the teaching of argumentation

Naheed Parween Anwar   Aga Khan University   naheedparveenanwar@gmail.com
                              Karachi, Pakistan

Muhammad Abid Ali   Bahria University   muhammadabid.buic@bahria.edu.pk
                              Islamabad, Pakistan

Abstract

Students should have the capability to argue about controversial science issues that are relevant to them and that impact society. These controversial issues, called socio-scientific issues (SSI), are influenced by social, ethical and moral norms. In current science education platforms, student-centred teaching strategies based on constructivism, are recommended to engage students in the construction of knowledge. Using a quantitative design, the present study sought to explore the efficacy of an argumentation-based teaching intervention about SSIs in an undergraduate classroom. It assessed students' gains in the skill of argumentation. A one-group pre-test-post-test design was used. Data were generated through collection of students' writing pre- and post-instruction, which was analysed using Toulmin's Argumentation Pattern (TAP). Results reveal that almost half of the students reached a high level of argumentation. Findings show the importance of teaching content through learner-centred pedagogies. Introduction of various socio-scientific case studies and practicing argumentation has positively impacted on students' argumentation skills. This study is significant for teachers as it provides an example to replicate in their classroom and can assist science teachers to enrich teaching and learning. The study recommends improving teachers' competence in order to promote argumentation skills among students.

Introduction

Science education in the 21st century demands involving students in the construction of knowledge, applying it in their daily life experiences for better understanding and using that understanding to make informed decisions about scientific issues (Hodson, 2010; Anwar & Bhutta, 2012 &, 2014). To achieve this, Newton, Driver and Osborne (1999) have recommended helping students understand scientific practices and thinking critically about scientific issues that impact their lives. That is why researchers and science educators have guided teachers to identify daily life scientific issues and engage students in a process of debate and structured discussion on such problems (Dawson & Venville, 2013). Such an experience may provide students an opportunity to achieve scientific literacy – a major goal of science education (Newton *et al*, 1999; Dawson, 2001). Argumentation is considered a central component of science education and the process of argumentation may help students make decisions now and in future (Driver, Newton & Osborne, 2000). Unfortunately, students in Pakistan are exposed to traditional ways of teaching, where students passively receive knowledge, transmitted by teachers, with few opportunities to apply that knowledge in their daily life experiences. Hence, they struggle to build links between science and society (Anwar, 2008). Due to this limited understanding of the world around them, students often fail to contribute to public debates and make informed decisions about scientific issues that impact their lives (Hodson, 2010).

In Pakistan, it has been widely believed that one of the teacher's roles is to help students memorize knowledge given in textbooks in order to gain good marks in their assessment (Halai & Khan, 2011; Parveen, Mahmood, Mahmood, & Arif, 2011). The lecture is the most popular teaching methodology despite the fact that this does not lend itself to student involvement in the lesson (Mahmood, 2007). Consequently, the classroom culture does not favour collaboration and student participation (Ahmad & Mahmood, 2010; Halai & Khan, 2011; Ali, 2012; Parveen & Batool, 2012). Various research studies indicate that innovative teaching methods are not understood and appreciated by teachers in Pakistan (Sarwar, 2001; Inamullah, Hussain, & Ud Din, 2008; Naseer, Patnam & Raza, 2009; Parveen, *et al*, 2011). For these reasons, teachers limit themselves to a traditional textbook approach and emphasize only the transfer of factual information about science processes, without applying it to solving real problems in society. For instance, students at school and college levels know how new pharmaceuticals, agricultural chemicals and polymers are used to make CDs, cellular phones and synthetic fibres (Awan & Khan, 2013). However, a relevant question about how these artefacts of modern advancement affect the environment is not discussed in the classroom.

Educational psychologists and researchers have since recommended a paradigm shift from teaching towards learning. This shift from the teacher to student has resulted in the growth of 'student-centred learning' as an alternative approach. McCabe and O'Connor (2014) reinforce student-centred learning as a shift in the ownership of learning, from teacher-lecturer to students. In such learning environments, students, as active participants, demonstrate proactive and constructive engagement in the learning process, in contrast to passive receiving of knowledge (Hua, Haris & Ollin, 2011; Najmonnisa & Saad, 2017). To explain student-centredness, Neumann (2013) has proposed a framework with three different aspects of student-centred learning environments: (i) allowing students to control and manage learning based on their interest; (ii) teachers create and provide authentic learning activities that lead to predetermined learning goals which students achieve by solving problems in their own ways; and, (iii) emphasis on the reciprocal relationship between

students and teachers that relies on learning partnerships and collaboration. Extending this further, Lee and Branch (2018:585) suggest that faculty follow three principles and assumptions to design student-centred learning environments: "(i) students as active constructors of meaning; (ii) knowledge constructed in authentic contexts; and, (iii) teachers' guidance and support for students' learning." Singh and Yaduvanshi (2015:2) explain that learners construct knowledge on the basis of their interaction with the environment.

In a student-centred classroom, the teacher provides authentic learning activities to achieve pre-determined goals. In this context, students construct knowledge while interacting with the environment. Correspondingly, socio-scientific issue (SSI) based discussions could help students to apply knowledge, learn by communicating their understanding and experiences, and develop skills to argue scientifically. SSIs are conceptually complex, multi-layered and open-ended cases. Debates on such SSIs require understanding of the nature of science to see the impact of science on society (Sadler & Dawson, 2012). SSIs concern scientific knowledge that is controversial in nature that can provoke open discussion, that have ethical, moral, social and political influences, and that are often debated in public forums (Sadler & Zeidler, 2005a). A science curriculum that includes recent and varied examples of SSIs can help students become more aware of up-to-date scientific advancements and help them interpret data and information (Alsop & Hicks, 2003). It is evident that a better understanding of scientific concepts has a positive relationship with improved argumentation skills (Zohar & Nemet, 2002; Sadler, Barab & Scott, 2007; Kolarova, Hadjiali & Denev, 2013). However, SSI-based argumentation in science education is an under-utilized approach that remains relatively unexplored in Pakistan. There is thus a need to introduce SSIs into science classrooms. The responsibility lies with science teachers to engage students, particularly female students, to make informed decisions about controversial issues associated with scientific discoveries and advancement. Due to cultural influences, females in the Pakistani context are seen as having less understanding of the world as compared to males. As a result, they are not consulted or heard in most family decisions (Latif, 2009). This is in contrast to western contexts (Swain & Wallentin, 2009).

The motivation of our research is therefore to develop and assess argumentation skills, largely dormant among females in Pakistan, through discussing controversial issues such as genetics and the case of 'designer babies'. These students are transiting into adulthood and improved argumentation is likely to empower them in raising concerns and contributing to decision making in the future. Furthermore, at a broader level, this would also lead to an effort in cultivating democracy to empower and raise consciousness within society.

In line with this, the specific aim of this study was to identify the effect of argumentation-based teaching on students' argumentation skills in a specific area of science. In this case, the central SSI was related to genetics. As such, genetics content was taught using student-centred teaching strategies. Later, SSI cases and argumentation models were introduced in the classroom to improve students' argumentation skills. In particular, the study examined the structure of the students' argument developed through argumentation-based teaching.

Theoretical Framework

Argument, argumentation and scientific argumentation

A claim with justifications is called an argument (Kuhn, 1991). In other words, an argument is a decision supported by reasons (Means & Voss, 1996). Sampson and Clark (2008) have established a difference between the two terms, argument and argumentation, identifying one as an outcome and the other as a process, respectively. In other words, the process of generating arguments to support a claim is termed argumentation. Simon, Erduren and Osborne (2006) elaborate on this by extending the notion of argument to include claims, data, warrants, and backing – all of which are generated in the process of argumentation. Krummheuer (1995) explains that argumentation can be an internal process carried out by an individual, or can occur in the form of an individual convincing a group of listeners.

Argumentation is an essential part of science education, and is the backbone of many scientific processes. It exemplifies how scientists talk to each other. Arguments are a series of statements, while argumentation refers to the use of scientific justification to support a claim (Luft, Bell & Gess-Newsome, 2008). Scientific arguments are ways to explain what, why and how phenomena occur. That is why it is considered an important process for reasoning about 'ill-defined' and 'ill-structured' problems (Dawson & Venville, 2009). Unfortunately, despite its critical role in science education, it is seldom used in the teaching of science. Highlighting the importance of argumentation, Newton *et al* (1999) place argumentation at the centre of the philosophy of science and give emphasis to the teaching of argumentation in the science class at primary, secondary and tertiary levels. Students engaged in argumentation not only learn the rules of science but also enhance their knowledge.

Argumentation comprises both monologic and dialogic discourse. In science classrooms, students share knowledge through dialogic discourse (Osborne *et al*, 2004). Conversely, each student exhibits argumentation skills in an oral or written format, thus producing monologic discourse (Means & Voss, 1996; Sadler & Zeidler, 2005b). Being members of a democratic society, students' ability to argue scientifically is more important than ever before. Students hear about adverse climatic changes, carcinogens, food-borne illnesses, innovation in technologies, and so on, and it is necessary to prepare them to participate in society in a meaningful way. Therefore, it appears critical to incorporate these socio-scientific issues into the science classroom to facilitate argumentation and build students' competency in making scientific arguments.

Importance of socio-scientific issues in science education

The development of scientific knowledge and technological advancement has changed the world. At the same time, the nature of science education has also changed significantly. However, despite urgent calls from science teacher-educators and researchers, evidence suggests that the thrust of science teaching remains factual content. Generally, science as a discipline is presented as a set of rules, principles and theories that are largely irrelevant to daily life (Anwar, 2008; Awan & Khan, 2013). However, science is recognised as increasingly value laden. Contemporary science education, in general, and the teaching of SSIs, in particular, attempts to give students a coherent view of science, that includes the skills and moral values needed to grapple with the daily issues students may encounter. SSIs concern scientific knowledge that is controversial in nature, which can provoke open

discussion that have ethical, moral, social and political influences, and that are often debated in public forums (Sadler & Zeidler, 2005a). This requires the introduction of new pedagogies in the science classroom which invites open discussions about technological advancements, their impact on individual lives and on society in general. The onus lies on science teachers to equip students with advanced scientific knowledge and competencies to analyse the benefits or threats of such advancements on human lives and society at large.

Researchers have used case studies to teach SSI-based argumentation. Examples of such cases include: genetic engineering for the production of insulin and the use of gene therapy in the treatment of cystic fibrosis (Lewis & Leach, 2006; Kolarova *et al*, 2013), the use of nuclear energy (Wu & Tsai, 2007), renewable energy (Wolff & Mnguni, 2015), global warming (Sadler & Zeidler, 2004; Khishfe, Alshaya, BouJaoude, Mansour & Alrudiyan, 2017), metal extraction (Vázquez-Alonso, Aponte, Manassero-Mass & Montesano, 2016), animal transgenesis (Simonneaux, 2001), human anatomy and physiology (Fowler, Zeidler & Sadler, 2009), genetically modified foods (Walker & Zeidler, 2007; Foong & Daniel, 2013; Khishfe *et al*, 2017), DNA registration, growing of stem cells, possibilities of bio-techniques and genetically modified organisms (Berne, 2014), human genetics (Zohar & Nemet, 2002), issues of cloning and designer babies (Venville & Dawson, 2010; Dawson & Venville, 2013; Berne, 2014), communicable diseases including HIV and AIDS (Wolff & Mnguni, 2015), use of bio-technology to identify sexually transmitted viral diseases (Sadler, Romine & Topcu, 2016), acid rain and human cloning (Khishfe *et al*, 2017), health risks of sweeteners such as aspartame, and the negative health effects of cell phone radiation (Strømsø, Bråten & Stenseth, 2017). This list indicates inclusion of diversified cases within the curriculum and classroom teaching, and these issues have an impact on human lives.

Quality argumentation requires explicit instruction

Argumentation is a process of formulating claims, justifying these with valid reasons, and drawing conclusions. Kuhn (1991) advocates the importance of engaging students in opportunities to critically evaluate claims against evidence and reasons. This is a skill that cannot be learned automatically. Students require step-by-step support, practice and modelling (Kuhn, 1991; Hogan, 2002; Zohar & Nemet, 2002). That is why researchers have used real life problems as a means to practice formal reasoning. This helps students locate such examples in their own social contexts and think critically about the impact of these problems in their society, allowing them to think about the moral, ethical and social aspects of the problem. Several research studies have been conducted to study argumentation in the science class (Osborne *et al*, 2004; Sadler & Donnelly, 2006; Dawson & Venville, 2009) and all have found that students need comprehensive guidelines in order to compose quality arguments. Jiménez-Aleixandre, Rodriguez & Duschl (2001) stress the critical role of teachers in promoting students' argumentation skills.

A framework to analyse SSI-based argument

The British philosopher, Toulmin (1958, 2013), developed the Toulmin Argumentation Pattern (TAP) as a practical approach to argument analysis. The TAP framework is widely used in designing and assessing argument in science education studies. It involves identifying the various components of an argument, namely claims (assertion, proposition or conclusion), data (evidence to support claim),

warrants (relationship between dada and claim), backing (assumption to support warrant), qualifiers (conditions under which claim is true), and rebuttals (condition to discard the claim) in a sequential order. This model of argumentation exhibits dual significance. In outlining the complexity of the structure of argument, it can be used to teach students the skill of argumentation, but also to analyse the arguments that students generate.

The advantage of Toulmin's model is that it is not content-specific. As such, it has been used as an analytical tool in much research aimed at evaluating the quality of argument produced by students and teachers (Krummheuer, 1995; Jiménez-Aleixandre *et al*, 2001; Zohar & Nemet, 2002; Osborne, *et al*, 2004; Cetin, 2014). In a large scale study, Dawson and Venville use this framework for students' oral and written arguments about socio-scientific issues (Dawson & Venville, 2009; Venville & Dawson, 2010, Dawson & Venville, 2013). In that study, TAP was applied to assessment of students' arguments in the form of a scoring rubric developed in the initial phase of the research (Dawson & Carson, 2017). In another study, a three-level analytical framework – the Science Argumentation Assessment (SAA) instrument – was used to assess the quality of argumentation in statements produced by individuals (Weng, Lin, & She, 2017).

Depending upon the research agenda, TAP has been modified and used in different ways by a number of researchers (Erduran, Simon, & Osborne, 2004; Sadler & Fowler 2006; Sadler & Donnelly, 2006; Simon *et al*, 2006; Sampson & Clark, 2008; Simon & Johnson, 2008; Grace, 2009). For example, to analyse high school and undergraduate students' interviews, Sadler and Fowler (2006) developed and used an argumentation rubric with numerical values 0 – 4. Sadler and Donnelly (2006) developed a rubric to classify argumentation patterns and evaluated the grounds provided by high school students to justify their claim. A simplified pattern of TAP was developed by Simon and Johnson (2008) to assess high school written and oral arguments. Erduran, Simon, and Osborne (2004) used TAP to trace the quality and quantity of argumentation in science discourse over time.

Methodology

This study set out to explore the efficacy of SSI-based science teaching in improving students' argumentation skills and informal reasoning. The paper focuses on only one component: the structure of arguments generated by students. The research question which guided this research is: how does argumentation-based teaching inform the structure of students' arguments about a selected socio-scientific issue? In order to determine whether there was a significant improvement in argumentation skills after treatment, a pre-experimental one-group pre-test-post-test design was used (McTavish & Loether, 2002; Abbot & McKinney, 2013; Johnson & Christensen, 2014; Punch, 2014).

The study was conducted in a women's public college in Karachi, Pakistan. Purposive sampling was done in order to select the college, with two specific criteria for inclusion: location in the centre of the city (as women from different cultural backgrounds and different regions of the city were likely to be enrolled in such a college), and offering zoology as a subject at Bachelor of Science level. The students in the zoology class at the selected college agreed to participate in the study. The medium of instruction in the college is English and all students were well versed in the language of instruction. All classroom processes were conducted in English. The 'designer babies' case study that was used to collect data (see Appendix 1) was also in English. Everyone was encouraged to contribute without the

need to provide only 'correct' answers. Students shared their opinion confidently, and an encouraging environment was fostered. The registered number of students in the class was 225. Absenteeism rate was high: the subject teacher noted that a majority of students studied at home but attended practical classes regularly. Since the practical classes had not started, a large number of students stayed at home. Still, a good proportion of students (more than one hundred) attended each class. Of this group, 52 completed both the pre- and post-test designer babies case study (see Appendix 1).

This study formed part of an M.Phil Education programme and the Board of Advanced Studies and Research provided the required ethical approval. All research ethics procedures were followed. The university approval letter and information sheet were shared with the research participants and officials before the intervention was conducted. Written consent was sought from the college principal, the head of the Zoology department, the subject teacher and the students.

Planning and implementing argumentation in the classroom

Observation of the instruction of the target class, prior to the intervention, indicated a transmission mode of teaching being used. For the research intervention, teaching content was selected from the approved college curriculum and negotiated with the subject teacher. Extensive day-by-day planning was done by the researcher. In planning and teaching, the researcher followed previous research done in this area, which suggested enhancement of content knowledge (Zohar & Neimet, 2002), explicit teaching of argumentation (Osborne *et al*, 2004; Venville & Dawson, 2010) and a facilitative role on the part of the teacher (Erduran *et al*, 2004; Lewis & Leach, 2006; Sadler & Donnelly, 2006; Simon *et al*, 2006). Before implementation, students answered the questions on the designer babies case study, as a pre-test (see Appendix 1). The post-test was administered at the end of the intervention by the teacher and in the absence of the researcher.

Teaching was primarily done by the researcher. Acknowledging the constructivist philosophy of learning, different student-centred pedagogies were used to teach genetics content in the classroom during the intervention. Each new learning episode was linked to the previous concept and moved towards a more advanced concept. Students were assisted to build new understandings from previous knowledge. It was observed that the students were highly engaged in varied experiential learning tasks. Content-appropriate pedagogy was used to ensure maximum learning through songs, analogies, videos, case studies, modelling and role play (see the lesson plan in Appendix 2). After the content teaching, different SSI cases were introduced in order to practice argumentation. Each SSI example was introduced strategically in order to move from simple to more complex cases. Cases were discussed in order to see the impact at individual and societal levels, and for present and future generations. This helped to reinforce the point that the latest scientific advancements have direct connections with important SSIs. Knowledge of the Toulmin Argumentation Pattern (TAP) and further practice was designed to help students understand how the argumentation process and conceptual understanding affect argumentation quality (Sadler & Donnelly, 2006). Students worked in groups, pairs and individually. These tasks provided less confident students an opportunity to listen before articulating their own arguments.

At different stages of the intervention, the teacher-researcher played different roles. During group and pair discussions, the researcher scaffolded students' learning by listening to students' discussion,

taking notes for further deliberation, playing devil's advocate, moderating the discussion, and prompting students to think from various angles. Similarly, during whole-class discussion, the teacher-researcher guided learning by providing additional arguments, taking notes on the board, classifying statements according to the TAP, and reflecting on the scientific reasoning of the arguments presented (see an outline of the teacher's role in Appendix 3). At the end, the post-test instrument was given to each student and they were required to register their claim with reasons, backing and rebuttal. The pre and post-tests were administered one day before, and one day after the intervention, respectively (Gorard, 2003). 'Experimenter effects' (Gorard, 2003:166) were taken account of by giving all instructions at the outset – as in an examination setup.

Data collection tool

The content focus for this research was genetics-related topics. To see the relationship between the intervention and the outcomes achieved, the same genetics-based 'Designer Babies' case study was used to collect data as a pre- and post-intervention tool (see Appendix 1). Lewis (2000) originally developed this tool, which was later used by Venville and Dawson (2010). In this research, the designer babies case was used as a trigger to help students construct claims and support claims with data, backing, counterclaims and rebuttals. The case of designer babies presented the open-ended, hypothetical scenario of producing babies with selected qualities at the request of parents and at a significant cost. Some guiding questions were provided to help students' argumentation and collect their responses. Each question focused on one element of the TAP. While answering the first two questions, the students provided warrants for their claims. Questions 3 and 4 asked them to justify their claims from different perspectives in order to strengthen their claims. The highest level of argumentation is counter claim and rebuttal. Questions 5 and 6 prompted them to think about others' perceptions as counter claims and provide rebuttal thereof to strengthen their claim. Each student answered these questions individually. While answering both the pre- and post-test, they answered all or some questions according to their understanding. Being a socio-scientific topic, the case study invited students to consider moral, cultural, religious and ethical aspects of the situation, which are core to such topics.

Data analysis

Data were collected using a scenario (the case of 'designer babies') and analysed quantitatively by assigning levels to students' comments. Toulmin's Argumentation Pattern (TAP) defines levels 1 to 6 (see Appendix 4), which were used to mark each student's writing. Each level progresses to the next by adding claims, warrants, data, backing, and qualifiers. Level 1 included the claim (conclusion or proposition only). Level 2 contains a claim, data (evidence supporting the claim) or warrants (relationships between the data and claim). Level 3 adds backing (assumption to support warrant) along with claim and data/warrant. Similarly, Level 4 consisted of claim, data/warrant, backing and qualifier (conditions under which claims are true). Levels 5 and 6 are based on Kuhn's (1991) descriptions. The counterclaim is an argument that contrasts with a person's own theory (Level 5), and rebuttal refers to producing counterarguments to that counterclaim (Level 6).

25% of the total writing frames (13 out of 52 pre-post sets) were used to establish inter-rater reliability and confirm consistency of the rating. The teacher-researcher, and an experienced rater, blind coded

the students responses provided in the designer babies case independently. The experienced rater had conducted similar research and had experience rating students' work using the TAP levels. Weighted Kappa was used to check inter-rater reliability of the coding. The coefficient value was 0.89 (usually lies between 0 – 1) which showed that coding was reliable and rating was aligned to TAP specifications.

Assigning levels of argumentation to students' work

The TAP framework for argumentation (Toulmin, 1958, 2003; Kuhn, 1991; Venville & Dawson, 2010) was used to analyse students' arguments during pre- and post- intervention. As already discussed, each guiding question in the data collection tool referenced a specific component of the TAP model. Ideally, by answering all questions, students should have reached Level 6 of TAP. However, simply answering all questions was not sufficient. The student was recorded as having achieved a specific level of argumentation only if the student's responses matched the definition or descriptions mentioned in TAP for each level. These levels of argumentation were differentiated on the basis of the presence or absence of the parts of argument mentioned in the TAP framework. Each level required higher levels of argumentation. Each student's response was read line by line and each statement was allocated to a component of argumentation. During this process, judgements were made as to whether the answer satisfied the component/s of argument specific to a particular level of argumentation. The final level achieved corresponded to the highest level of argument identified.

Student's work was marked as Level 1 if it contained a claim only, which was required, as the students could only answer 'yes' or 'no' in response to the given question. The respondents achieved Level 2 if they provided adequate evidence, in the form of data and/or warrants to support their claim. The justification did not necessarily have to be statistical evidence or quotes from literature, but students own reasons to support their claim were acknowledged; this included reflection on contextual realities, ethical underpinnings, religious or moral beliefs, opinion or any scientific reason (Venville & Dawson, 2010). Level 3 was allocated to students' work if it included arguments that consisted of a claim, data/warrant and backing. Student's work was assessed at Level 4 if it included a claim, data/warrant, backing and a qualifier. Similarly, Level 5 was designated if a student's response also included a counter-claim. The highest level of argumentation, Level 6, was assigned to a student's work if the written response included all components of argumentation mentioned in TAP. Descriptions of each level (1 to 6) with some excerpts from different student's post-test answers are given in Table 1, which is adapted from an MPhil research thesis (Anwar, 2017).

Table 1. Analytical framework for assessing the quality of argumentation with examples of students' work. Adapted from Anwar (2017).

Level	Description	Examples from students' work
Level 1	Claim (statement, conclusion, proposition only)	Yes No

Level 2	Claim, data (evidence supporting the claim) or warrant, (relationship between claim and data)	No, we should not create children of our desire (claim). Natural features and habits of the children should not be changed (warrant). Instead, this technology should be used for the treatment of ill people (data). Everything happening in this world has a purpose, we should respect it. If we use this technology to change the normal routine and processes, we might damage the natural balance maintained in this world (data). Humans are created by God; we have no right to change something which is made by God (data).
Level 3	Claim, data / warrant and backing (assumptions to support warrant)	No (claim), through gene modification, the natural identity of the family will be spoiled (warrant). This process is not reversible (data). This technology will affect the gene pool of that family. The genetic makeup of the individual and of the next generation will be modified (backing). Human race will lose diversity and the cultural & regional genetic marker will disappear (data/warrant).
Level 4	Claim, data/warrant, backing and qualifier (the condition under which claims are true)	No, it is just cheating (claim). This is ethically wrong (warrant). We do not take the consent of the baby whose genetic makeup would be modified. Baby might not like this type of change in his/her body (backing). The child might regret not carrying original identity (data). He might keep a distance from his parents (data). Above all, the individual identity of the child will be destroyed (data). The child would not be able to know what original characteristics he/she could have otherwise (without undergone gene therapy) (backing). If the child acquires any chronic disease due to this technology, he will blame his parent for the illness and this will create a distance between the child and parents. The idea to use this technology for testing of genetic disorder is good (qualifier).
Level 5	Claim, data/warrant, backing, qualifier and counter claim (an argument that contrasts with person's own theory)	No (claim). By this therapy, our society will be divided into classes (warrant). This technology is beyond the reach of every human being (backing). There will be differences between designer and non-designer children in our society (data). Non-designer babies may not have job opportunities (data). Society is already divided into classes and everyone does not have job opportunity so why stop the use of technology (counter claim). By this therapy, our society will have more intelligent, pretty and healthy people who will be good (counter claim). These intellectual children will put a positive impact on the economy of the country (counter claim). By such therapy, these children will open the door for advanced technologies (counter claim). Because of gene modification technology, genetics linked diseases will be cured in the future (counter claim). If scientists provide us the proof that the therapy is 100 % safe from all disease. The third party verifies the result of

this research. If there will be no difference between designer and non-designer babies, only then I will change my decision (qualifier).

Yes, (claim). Parents would get a chance to have child of their choice. Gene modification technology (GMT) would provide them a chance to have male children (warrant). In our society, mothers are blamed to be responsible for the birth of female children. Family members curse that lady for not giving birth to a male child (data). Through this technology, such families can have male child. This way mother would not suffer from ill treatment of the family (in laws). As a result many women would not suffer from divorce (backing). Through this technology, prosperity will excel in the society (backing). Humans are created by God, so, it is wrong to create the babies of our needs (counter claim). We should work to change mind set of the people (counter claim). I don't like the idea of creating boys and providing a chance to such families. Instead, I would prefer counselling (qualifier).

Level 6	Claim, data / warrant, backing, qualifier displaying and extended argument with rebuttal to answer counter claim.	Yes (claim). Most probably, this gene technology would be used for the prevention of diseases (warrant). Next generation would be healthier and prosperous (data). Incurable diseases will be eradicated (backing). The next generation will suffer from less diseases. With the passage of time, this technology will improve (data). Scientists are human beings after all. There are chances of error. The newly inserted gene may not function properly (counter claim). Vector used for gene delivery may affect mother and cause diseases (counter claim). If the process is not followed cautiously, the child life may terminate (counter claim). Creating a generation of genetically modified humans could cause a disturbance in evolution in unpredictable ways (counter claim). Scientists are providing a guarantee that the babies would be free from identifiable genetic diseases (rebuttal). A lot of experiments have been done to check the process (rebuttal). The procedure for gene transfer is very safe; no harm is attached for the child and mother (rebuttal). The gene will be transferred through well though and piloted checked procedures (rebuttal). I will change my decision if I come to know that the process is not safe for the child and mother (qualifier).

An example of achievement of Level 6 argumentation is presented in Table 1. As can be seen, this student's claim is that the gene technology should be allowed. The student provided evidence to support her claim: "Next generation would be healthier and prosperous". This evidence is based on the warrant that: "Most probably, this gene technology would be used for the prevention of diseases".

45

A warrant should explicitly link a claim and data (Toulmin, 1958, 2003). Because of this, data and warrants were considered together in this data analysis scheme. Backing provides information to support the warrant or strengthen data. In this example, the student wrote: "Incurable diseases would be eradicated". This assumption supports the student's warrant that: "Most probably, this gene technology would be used for the prevention of diseases". In addition, the student has analysed the situation from another's perspective and has provided many counterclaims, all related to the health of mother and child and the risk factors associated with the use of this technology. The student writes: "There are chances of error… vector used for gene delivery may affect mother and cause diseases…if the process is not followed cautiously, the child life may terminate". The student clearly explains and rebuts these counterclaims to strengthen her own claim. She provides rebuttal as follows: "Scientists are providing a guarantee that the babies would be free from identifiable genetic diseases… A lot of experiments have been done to check the process … The gene will be transferred through well though and piloted checked procedures". After analysing the pros and cons of technology, the student has also produced a qualifier, by elucidating that the technology given in the scenario should ensure safety: "I will change my decision if I come to know that the process is not safe for the child and mother".

All data collected were assigned an argumentation level based on this method of analysis. The level achieved by each student was analysed using SPSS (21.0). As the distribution was not normal, a non-parametric Wilcoxon Sum Rank Test was used to compare the pre- and post-test results. To measure the magnitude of the differences, effect size was computed.

Findings

Shifts in argumentation before and after intervention: Qualitative description of case study

As previously discussed, all students were required to answer all the questions on both the pre- and post- test tools. However, some did not answer all the questions or the responses failed to match the descriptions in the TAP. During the intervention, the components of argumentation were introduced and different SSI cases were used to practice argumentation. As a result, students were able to argue by including the components of argumentation in their responses. Through this exercise, students were able to write comprehensive arguments and achieve higher levels of argumentation in their post-test assessment. An example is given below that shows progression in the argumentation of a particular student. In the pre-test, this student presents data, warrants and backing to justify their claim. In the post-test, the same student was again able to defend her claim with adequate data, warrant and backing, but also aptly rebuts a counter claim. The excerpts below in Table 2 are presented without any grammatical correction. The indicators of the levels identified (claim, data/warrant, backing, counterclaim and rebuttal) have been added in parentheses.

Table 2: Sample student's pre- and post-test responses, illustrating their progression from TAP Level 3 to Level 6 due to pedagogic intervention. Adapted from Anwar (2017).

Pre-intervention	Post-intervention
No (claim). The technology is not 100% safe, still in experimental stage (warrant). This technology will affect the gene pool of that family. Genetic makeup of the individual and of the next generation will be modified (data). If the process is not done correctly the embryo could be terminated accidently (data). Humans are created by Allah, so it is wrong to try genetic makeup of someone that has been made by Allah (backing).	No (claim). There is no guarantee that this technology is safe 100% (warrant). Creating generation of genetically modified humans could cause disturbance in evolution in unpredictable ways (backing). The process is risky and can damage mother or child. Gene technology is evolving (data). The process is not cheap and not everyone can afford it. This will create classes, people who can afford and poor people who cannot (data). This will cause less job opportunities for non-designer babies (data). Such gene technology will open doors for more advanced technologies in future (counter claim). Using this technology, scientist will prevent genetic diseases like Down syndrome, Huntington disease etc. (counterclaim). Humans are created by Allah, we have no right to change something which is made by Allah (rebuttal). We do not take the consent of the baby whose genetic makeup would be modified. This is ethically wrong (rebuttal). I will change my decision only if there is responsible management and involvement of third neutral party for monitoring the whole process and results (qualifier).
Overall level of argumentation achieved: 3	**Overall level of argumentation achieved: 6**

The results reveal significant gains (p<0.01) in students' argumentation skills and the complexity of the structure of their arguments. As shown in Figure 1, a marked improvement in argumentation was observed after the intervention. The magnitude of difference (r=0.79) was large. Almost half of the students (n=23; 44.2%) attained the highest level of argumentation in the post-test. Before the intervention, only a few were at Level 6 (n= 3; 5.8%), while most of the students only met Level 2 (n=31; 59.6%). Surprisingly, all the students' post-test comments were scored at least Level 2 and not a single student's comment was classified as Level 1 on the TAP (T= 903.0; z = - 5.68; p< 0.01). Figure 1 shows that before instruction, the incidence of Level 2 argumentation was most common, while after the instruction, most students argued at Levels 5 and 6.

Pre and Post Instruction Argumentation
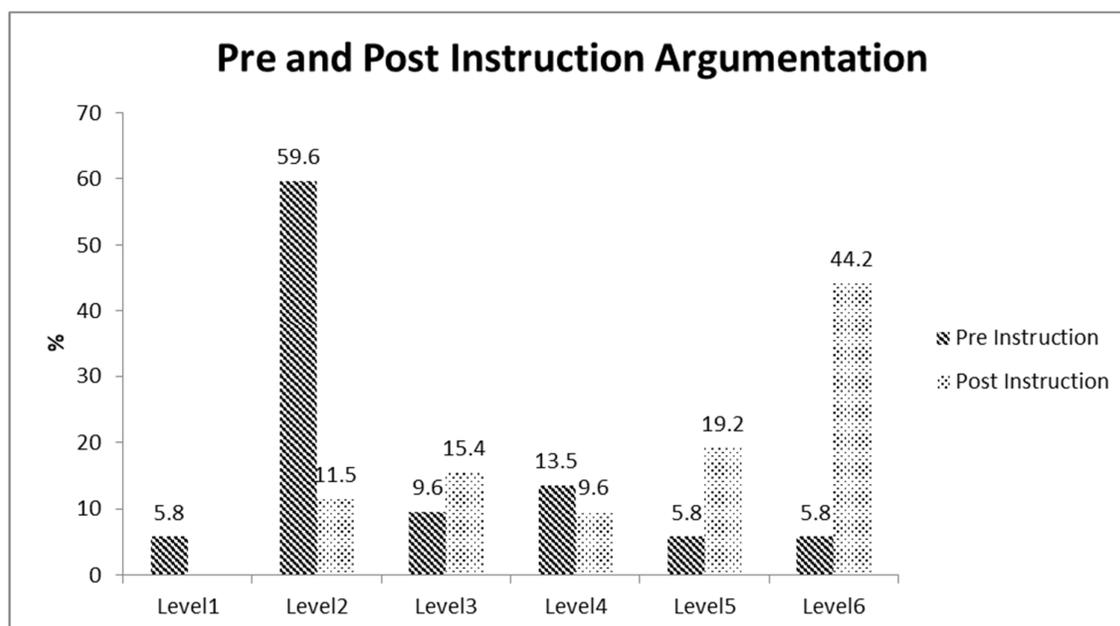
Figure 1: Pre- and post-instruction argumentation levels. Adapted from Anwar (2017).

Discussion

This study used a one group pre- and post-test research design. The findings show that the designed intervention contributed positively to enhancing the structure of students' arguments around a given SSI. It appears, that student-centred interactive strategies based on constructivist ideals of teaching, produced a positive correlation between the knowledge gained and the level of argument generated.

Student-centred learning grants students greater ownership of learning and shifts responsibility from teachers to students (O'Neill & McMahon, 2005). Specifically, the teacher-researcher followed the principles indicated by Lee and Branch (2018) by ensuring a learning environment where students actively constructed knowledge in an authentic context with the teacher-researcher's guidance and support. Throughout the intervention, students actively participated in their own learning, constructed new knowledge and skills on their existing knowledge, worked in collaboration with other learners and produced work that demonstrated authentic learning. These roles matched with the American Institute for Research's (2010) described roles and responsibilities for a student-centred classroom. Different student-centred strategies were used during this intervention, thus confirming the ownership of learning and assuring proactive and constructive engagement of students in the learning process. Students had opportunities to compare, examine, and refine their knowledge with understanding from other members of the class. Hands-on experiential learning tasks, case studies, inquiry-based situations, modelling and role-play were employed to help students apply knowledge in real-life situations (see Appendix 2). The teacher-researcher provided a range of learning experiences for each learner to elaborate their own prior knowledge. This is in tandem with Neumann's (2013) framework of student-centredness, as the teacher-researcher provided authentic learning activities to achieve pre-determined learning goals. As such, the researcher led less and facilitated more to model this shift from teacher to students. The intervention was designed in line with the graduate

level curriculum. The significance of this is that content was covered at length through different strategies and argumentation skills were explicitly focused on. The TAP framework was introduced and explained after content sessions. Different SSI cases (relevant to their lives and society) were used to practice argumentation. During this interactive process, information and knowledge were provided and exchanged in pairs, groups or through whole-class discussion to establish authentic learning. As such, students reached the highest level of argumentation by including counter-claims and rebuttal.

The constructivist theory of learning suggests that students construct knowledge and meaning from their experience (Duit & Treagust, 2003). In the classroom, this theory points teachers towards different active teaching practices, such as experiments, real-world problems, inquiry, and so on. It aims to encourage students to create new knowledge from pre-existing understandings. It also encourages students to reflect on and talk about what they do, and how their understanding changes, by questioning previous knowledge, building new understandings and developing a holistic understanding of a concept. Through argumentation, students can recall, apply and critique knowledge in order to build consensus. However, students should know the basic 'rules of the games' as an initial threshold. Achieving an initial level leads to a second threshold based on advanced knowledge (Sadler & Donnelly, 2006). In this research, it was evident that the designed intervention enabled students to argue in an improved way after the intervention (see Figure 1). They were able to apply knowledge and argue about a given socio-scientific scenario. In this regard, this research is consistent with that of Zohar and Nemet (2002), Osborne, Erduran and Simon (2004) and Venville and Dawson (2010), in that it finds that content-specific strategies facilitate knowledge building. Venville and Dawson (2010) focus only on teaching of argumentation as the content was covered in previous lessons. However, Osborne, Erduran and Simon (2004) find that improvement in the quality of post-intervention argumentation was not significant when matched with a control group.

Argumentation is a process of formulating claims, justifying these with valid reasons, and drawing conclusions. Kuhn (1991) advocates the importance of engaging students in opportunities to evaluate claims critically. This is a skill that is not learned automatically. This research engaged students in the process, yet they did not have time to seek out evidence in the form of quotes from literature, present any case detail, or provide statistical data. Despite this, they were able to provide valid reasons in support of their main claim, present counterclaims and rebut those counterclaims to support their own claim. This study finds that 23 students reached Level 6 argumentation, as compared to only 3 students prior to the intervention. Achieving the highest level of argumentation indicates that these students were able to generate counterclaims and rebuttals after the intervention. This finding resonates with Kuhn's (1991) assertion that the ability of argumentation is present in each individual. Kuhn's analyses reveal that support and guidance enhance learners' capability regarding argumentation. Other researchers have reached the same conclusion. Zohar and Nemet (2002) observe that a 12-hour argumentation intervention improved the quality of argumentation. Wu and Tsai (2007) propose that teachers should guide students in analysing a situation from varied perspectives. Apart from the students who reached the highest level of argumentation, 10 students succeeded in achieving the second highest level of argumentation after the intervention, as compared to only 3 prior to the intervention. These students were able to identify counterclaims, but were unable to produce effective rebuttals to refute these counterclaims.

The components of argument (claim, data, warrant, backing, qualifier, counterclaim and rebuttal) specified in TAP were introduced and explained in the classroom. Each component was explained with simple examples. Different classroom settings with different SSIs were used, shifting from group work, to pair work and to individual tasks. In group tasks, students gave evidence *for* or *against* a daily life issue (such as, *smoking should be banned in big restaurants*). Important arguments were noted on the board, classified and discussed according to TAP. This gave students a chance to see how and why a given statement is or is not a component of TAP and clarified the component further. The students constructed the knowledge and, hence, internalized science content as well as argumentation skills. Group tasks provided students an opportunity to take a position individually, and share this with their group members, by providing scientific reasons, generating counterarguments and defending personal claims by refuting counterclaims. Such small group discussion helped students boost their confidence (Venville & Dawson, 2010). Similarly, whole-class argumentation provided students a larger platform for such interaction. They had opportunities to listen to and understand alternate views, compare these with their own ideas and reconcile their arguments in light of new learning. As a result, they achieved the highest levels of argument specified in TAP. This, we would argue, is in part because of the explicit teaching of the components of argumentation that took place beforehand as part of which students were assisted regarding how to argue in a scientific way.

Different SSIs were used by the researchers to help students understand the impact of scientific advancement on human lives and society. Most of these cases were genetics-related and presented social, moral, ethical and religious issues. Sadler *et al* (2007) recommend using relevant SSIs to support students' understanding, help them build links between science and society, and enhance their motivation to pursue science. During the intervention, different genetics-related SSIs were introduced. Questions about these issues were developed according to TAP. Students went through the same process of reading the case, answering questions, discussing the issue, and coming to a common agreement. Specific SSIs used in the classroom included cystic fibrosis (Kolarova *et al*, 2013), Huntington disease (Zohar & Nemet, 2002) and the case of Hollywood stars. Such multiple opportunities to practice argumentation using different SSIs might have improved students' content knowledge and built their argumentation skills (Zohar & Nemet, 2002; Foong & Daniel, 2013; Weng *et al*, 2017).

Throughout the intervention, the researcher played important and critical roles by planning and implementing content-specific lessons following a constructivist teaching philosophy. Twelve days of teaching and eighteen lessons were provided; this was in addition to the encouragement and facilitation extended by the researcher during group, pair and individual work. Students were required to present their ideas, listen to others' opinions, and negotiate ideas. During whole-class discussion and group work, the researcher promoted quality argument by listening quietly without giving opinion, encouraging debate, exemplifying argumentation, prompting for evidence, playing devil's advocate, encouraging students to think beyond the norm, and encouraging reflection. The researcher modelled the strategy, provided examples of the desired arguments, allowed time for students to adopt practices and analyse discourse on their own through different cases and modelling a TAP analysis of these cases.

Implications of argumentation-based teaching of SSIs for the Scholarship of Teaching and Learning (SoTL)

The changing nature of science education necessitates building links between scientific knowledge, its advancement, and its impact on society. This shift from simple transfer of knowledge toward debating its impact upon individual lives and societies has put great pressure on teachers. Hence, the findings of this research have significant implications for teachers and teacher education institutes. At the individual level, a teacher should understand the changing demands of science education by making it more applicable, demanding and socially-oriented. It is important to teach students the language of argument, so that they may weigh the pros and cons of any situation. Students should have an opportunity to build claims, give reasons and develop warrants. Teachers should develop situations in which students are required to work with other perspectives, in the form of counterclaims, and consider how to rebut these perspectives. In this way, students may analyse the advancement of science in terms of socio-scientific issues from different perspectives. The role of the teacher as facilitator was implicit during this intervention. Explaining the role of the teacher was not the aim of the research. However, we know that science teachers in the Pakistani context may lack the necessary skills to introduce this strategy in their science classes. Therefore, this research has the implication that teacher education institutes should train science teachers in this regard.

Conclusion

This is not an experimental study and, as such, causation cannot be claimed. However, this pre-experiment one-group pre-test post-test design (McTavish & Loether, 2002; Abbot & McKinney, 2013; Punch, 2014; Johnson & Christensen, 2014) has produced some promising outcomes. Enhanced levels of argument were found in the post-test as compared to the pre-test. Therefore, it can be said that SSI-based instruction may improve the structure of students' arguments. In the 21st century, we are faced with many socio-scientific issues because of scientific and technological advancements. Some of these developments, despite many advantages, may be considered risky and disadvantageous. Current science education aims to equip students with argumentation skills in order to develop more informed participation in critical SSIs. Therefore, it is encouraging to note that, in this study, students participated actively in the process. They developed conceptual understanding of the content, had information about SSIs and built argumentation skills, thus acquiring a degree of functional scientific literacy. Therefore, it can be said that SSI-based instruction is an effective way to increase students' argumentation quality.

To engage in well-informed discussion, content knowledge is crucial. Use of relevant SSIs motivates students to engage in discussion on controversial topics. This study also suggests that the teacher has a vital role to play in guiding students towards various dimensions of an issue, building the required knowledge, guiding students in the process of practicing argumentation, and providing SSIs that are relevant to students' lives and have roots in society. Daily life, contemporary and controversial issues help students to make claims, and support these through warrants and develop backing for these warrants. Guidance and practice are necessary elements of this process. It takes time and significant pre-planning in order to introduce argumentation to a class, and science teachers should be capacitated to facilitate such developmental pedagogy.

References

Alsop, S. & Hicks, K. 2003. *Teaching Science; A Handbook for Primary and Secondary Teachers.* New Delhi: Kogan Page.

Anwar, N. 2008. Promoting discussion in the lower secondary science classroom. *Journal of Research and Reflection in Education*. 1(2): 175-200.

Anwar, N.P. 2017. The effect of argumentation based teaching on students' argumentation skills, informal reasoning, and conceptual understanding. Unpublished MPhil dissertation. Institute of Business Management, Karachi, Pakistan.

Anwar, N. & Bhutta, S. 2012. Enhancing content knowledge of in-service science teachers through model & modeling. *Journal of Research and Reflection in Education.* 6(1): 61-74.

Anwar, N. & Bhutta, S. 2014. Students' Attitudes towards Science in Lower Secondary Classes: Comparison across Regions. *Journal of Educational Research*. 17(1): 77-91.

Ahmad, Z. & Mahmood, N. 2010. Effects of cooperative learning vs. traditional instruction on prospective teachers' learning experience and achievement. *Journal of Faculty of Educational Sciences*. 43(1): 151–164.

Ali, T. 2012. A case study of the common difficulties experienced by high school students in chemistry classroom in Gilgit-Baltistan (Pakistan). *SAGE Open*. 2(2): 1-13.

American Institute for Research (AIR). 2010. Teaching excellence in adult literacy. TEAL centre fact sheet # 6: Student centred learning. Available: https://lincs.ed.gov/state-resources/federal-initiatives/teal/guide/studentcentered. Accessed: 16 September 2020.

Awan A.S. & Khan, T. M. 2013. Investigating Pakistani Students' alternative Ideas regarding the Concept of Chemical Bonding. *Bulletin of Education and Research*. 35(1): 17-29.

Berne, B. 2014. Progression in Ethical Reasoning When Addressing Socio-scientific Issues in Biotechnology. *International Journal of Science Education*. 36 (17): 2958-2977.

Bhutta, S.M. & Anwar, N.P. (in process). Promoting Argumentation in Science Education Classrooms through Socio-Scientific Issues: A Case of Teacher Education Classroom. Unpublished.

Cetin, P.S. 2014. Explicit argumentation instruction to facilitate conceptual understanding and argumentation skills. *Research in Science and Technological Education*. 32(1): 1-20.

Dawson, V.M. 2001. Addressing controversial issues in secondary school science. *Australian Science Teachers' Journal.* 47(4): 38-44*.*

Dawson, V.M. & Venville, G. 2009. High school students' informal reasoning and argumentation about biotechnology: An indicator of scientific literacy? *International Journal of Science Education.* 31(11): 1421– 1445.

Dawson, V.M. & Venville, G. 2013. Introducing high school students to argumentation about SSI. *Canadian Journal of Science, Mathematics and Technology Education*. 22(31): 356-372.

Dawson, V. & Carson, K. 2017. Using climate change scenarios to assess high school students' argumentation skills. *Research in Science & Technological Education.* 35(1): 1-16.

Driver, R., Newton, P., & Osborne, J. 2000. Establishing the norms of scientific argumentation in classroom. *Science Education.* 84(3): 287-312.

Duit, R. & Treagust, D.F. 2003. Conceptual change: a powerful framework for improving science teaching and learning. *International Journal of Science Education.* 25(6): 671-688.

Erduran, S., Simon, S. & Osborne, J. 2004. TAPing into argumentation: Developments in the application of Toulmin's argument pattern for studying science discourse. *Science Education.* 88: 915-933.

Foong, C., & Daniel, E.G. 2013. Students' argumentation skills across two socio-scientific issues in a confucian classroom: Is transfer possible? *International Journal of Science Education.* 35(14): 2331-2355.

Fowler, S.R. Zeidler, D.L. & Sadler, T.D. 2009. Moral sensitivity in the context of socio-scientific issues in high school science students. *International Journal of Science Education.* 31: 279-296.

Gorard, S. 2003. *Quantitative methods in social science*. Chapter 4. Sampling the basis of all research. 56-89. London: Continuum.

Grace, M. 2009. Developing high quality decision-making discussion about biological conservation in a normal classroom. *International Journal of Science Education.* 31(4): 551-570.

Halai, N. & Khan, M.A. 2011. Developing pedagogical content knowledge of science teachers through action research: A case study from Pakistan. *Asia Pacific Forum on Science Teaching and Learning*. 12(1): 1-23.

Hodson, D. 2010. Science education as a call to action. *Canadian Journal of Science, Mathematics and Technology Education*. 10(3): 197-206.

Hogan, K. 2002. Small groups' ecological reasoning while making an environmental management decision. *Journal of Research in Science Teaching*. 39(4): 341–368.

Hua, Z., Harris, A. & Ollin, R. 2011. Student Autonomy and Awareness: Vocational Education and Student-centred Learning in China. *Journal of Vocational Education and Training*. 63(2): 191–203.

Inamullah, H.M., Hussain, I. & Ud Din, M.N. 2008. Teacher-students verbal interaction at the secondary level. *Journal of College Teaching & Learning.* 5(9): 41-43.

Jiménez-Aleixandre, M.P., Rodriguez, A.B. & Duschl, R.A. 2001. "Doing the lesson" or "doing science"; argument in high school genetics. *Science Education.* 84(6): 757-792.

Johnson, B. & Christensen, L. 2014. *Educational Research: Quantitative, Qualitative, and Mixed Approaches* (5th ed.). Los Angeles: SAGE.

Khishfe, R., Alshaya, F. S., BouJaoude, S., Mansour, N. & Alrudiyan, K. I. 2017. Students' understandings of nature of science and their arguments in the context of four socio-scientific issues. *International Journal of Science Education.* 39(3): 299-334,

Kolarova, T., Hadjiali, I. & Denev, I. 2013. High school students' reasoning in making decisions about socio-ethical issues of genetic engineering: Case of gene therapy. *Biotechnology and Biotechnological Equipment.* 27(2): 3737-3747.

Krummheuer, G. 1995. The ethnography of argumentation. In Cobb, P. & Bauersfeld, H. (eds.) *The emergence of mathematical meaning: Interaction in classroom culture*. Hillsdale, NJ: Lawrence Erlbaum.

Kuhn, D. 1991. *The skill of arguments*. Cambridge: Cambridge University Press.

Lee, S.J., & Branch, R.M. 2018. Students' beliefs about teaching and learning and their perceptions of student-centred learning environments. *Innovation in Education and Teaching International.* 55(5): 585 – 593.

Lewis, J. 2000. Making the science relevant: Classroom discussion of social issues with a science content. In: Bayrhuber, H. & Unterbruner, U. (eds.) *Lehren and lernen im biologieunterricht*. Innsbruck-Wein-Munchen: Studien Verlag. 107–119.

Lewis, J. & Leach, J. 2006. Discussion of socio-scientific issue: The role of science knowledge. *International Journal of Science Education*. 28(11): 1267– 1287.

Luft, J., Bell, R. L. & Gess-Newsome, J. 2008. *Science as inquiry in the secondary setting.* Arlington, Va.: NSTA Press.

Mahmood, N. 2007. Elementary School Science Teachers' Belief about Science and Science Teaching in Constructivist Landscape. *Bulletin of Education & Research.* 29(2): 59-72.

McCabe, A. & O'Connor, U. 2014. Student-centred learning: the role and responsibility of the lecturer. *Teaching in Higher Education.* 19(4): 350–359.

McTavish, D.G. & Loether, H.J. 2002. *Social research: An evolving process* (2nd ed.). Boston: Allyn and Bacon.

Means, M., & Voss. J. 1996. Who reasons well? Two studies of informal reasoning among children of different grades, ability and knowledge levels. *Cognition and Instructions.* 14(2): 139-178.

Najmonnisa & Saad, I. 2017. The Role of Cooperative Learning Method in Teaching of Science Subject at Elementary School Level: An Experimental Study. *Bulletin of Education and Research.* 39 (2): 1-17.

Naseer, F., Patnam, M. & Raza, R. 2009. Are child centered classrooms effective? Impact of the CRI program on student learning outcomes in Pakistan. *Economics of Education Review.* 669-683.

Neumann, J. W. 2013. Developing a New Framework for Conceptualizing "Student Centered Learning". *The Educational Forum*. 77(2): 161-175.

Newton, P., Driver, R. & Osborne, J. 1999.The place of argumentation in the pedagogy of school science. *International Journal of Science Education.* 21(5): 553– 576.

O'Neill, G. & McMahon, T. 2005. Student–centred learning: What does it mean for students and lecturers? In O'Neill, G., Moore, S., McMullin, B. (eds.) *Emerging issues in the practice of University Learning and Teaching*. Dublin: AISHE.

Osborne, J., Erduran, S., & Simon, S. 2004. Enhancing the quality of argumentation in school science. *Journal of Research in Science Teaching.* 41(10): 994-1020.

Parveen, Q., Mahmood, S.T., Mahmood, A. & Arif, M. 2011. Effect of cooperative learning on academic achievement of 8th grade students in the subject of social studies. *International Journal of Academic Research*. 3(1): 950-954.

Parveen, Q. & Batool, S. 2012. Effect of cooperative learning on achievement of students in general science at secondary level. *International Education Studies.* 5(2): 154–158.

Punch, K. 2014. *Introduction to Social Research: Quantitative and Qualitative approaches*. London: SAGE Publications.

Sadler, T.D. & Zeidler, D.L. 2004. The morality of socio-scientific issue: Construal and resolution of genetic engineering dilemmas. *Science Education*. 88:4-27.

Sadler, T.D. & Zeidler, D.L. 2005a. The significance of content knowledge for informal reasoning regarding socio-scientific issue: Applying genetics knowledge to genetic engineering issues. *Science Education*. 85: 71– 93.

Sadler, T.D. & Zeidler, D.L. 2005b. Patterns of informal reasoning in the context of socio-scientific decision-making. *International Journal of Science Education.* 42(1): 112– 138.

Sadler, T.D. & Donnelly, L.A. 2006. Socioscientific arguemntation: The effect of content knowledge and morality. *International Journal of Science Education*. 28(12): 1463– 1488.

Sadler, T.D. & Fowler, S.R. 2006. A threshold model of content knowledge transfer for socio-sciencitifc argumentation. *Science Education*. 90(6): 986-1004.

Sadler, T.D., Barab, S.A., & Scott, B. 2007. What Do Students Gain by Engaging in Socioscientific Inquiry? *Research in Science Education.* 37: 371-391.

Sadler, T.D. & Dawson, V.M. 2012. Socioscientific issues in science education: Contexts for the promotion of key learning outcomes. In Fraser, B.J., Tobin, K. & McRobbie, C. (Eds.). *The second international handbook of science education* Dordrecht, The Netherlands: Springer. 799–809.

Sadler, T.D., Romine, W.L. & Topcu, M. S. 2016. Learning science content through socio-scientific issue based instruction: a multilevel assessment study. *International Journal of Science Education*. 38(10): 1622-1635.

Sampson, V. & Clark, D.B. 2008. Assessment of the ways students generate arguments in science education: Current perspectives and recommendations for future directions. *Science Education.* 92(3): 447-472.

Sarwar, Z. 2001. Innovations in large classes in Pakistan. *TESOL Quarterly*. 35(3): 497-500.

Simon, S., Erduran, S. & Osborne, J. 2006. Learning to Teach Argumentation: Research and development in the science classroom. *International Journal of Science Education.* 28(2-3): 235-260.

Simon, S. & Johnson, S. 2008. Professional learning portfolios for argumentation in school science. *International Journal of Science Education.* 30(5): 669-688.

Simonneaux, L. 2001. Role-play or debate to promote students' argumentation and justification on an issue in animal transgenesis. *International Journal of Science Education.* 23(9): 903- 927.

Singh, S. & Yaduvanshi, S. 2015. Constructivism in science classroom: Why and How. *International Journal of Scientific and Research Publications*. 5(3): 1-5.

Strømsø, H.I., Bråten, I. & Stenseth, T. 2017. The role of students' prior topic beliefs in recall and evaluation of information from texts on socio-scientific issues. *Nordic Psychology.* 69(3): 127-142.

Swain, R.B. & Wallentin, F.Y. 2009. Does microfinance empower women? Evidence from self-help groups in India. *International Review of Applied Economics.* 23(5): 541-556.

Toulmin, S. 1958.*The uses of argument.* Cambridge: Cambridge University Press.

Toulmin, S.E. 2013. *The layout of arguments.* Cambridge: Cambridge University Press.

Vázquez-Alonso, A., Aponte, A., Manassero-Mas, M. & Montesano, M. 2016. A teaching–learning sequence on a socio-scientific issue: analysis and evaluation of its implementation in the classroom. *International Journal of Science Education.* 38(11): 1727-1746.

Venville, G.J. & Dawson, V.M. 2010.The impact of a classroom intervention on grade 10 students' argumentation skills, informal reasoning, and conceptual understanding of science. *Journal of Research in Science Teaching*. 47(8): 952-977.

Walker, K.A. & Zeidler, D.L. 2007. Promoting discourse about socio-scientific issues through scaffolded inquiry. *International Journal of Science Education*. 29: 1387-1410.

Weng, W-Y, Lin, Y-R & She, H-C. 2017. Scaffolding for argumentation in hypothetical and theoretical biology concepts. *International Journal of Science Education.* 39 (7):877-897.

Wolff, E. & Mnguni, L. 2015. The Integration of HIV and AIDS as a Socio-scientific Issue in the Life Sciences Curriculum. *African Journal of Research in Mathematics, Science and Technology Education.* 19(3): 213-224.

Wu, Y. & Tsai, C. 2007. High school students' informal reasoning on a socio-scientific issue: Qualitative and quantitative analyses. *International Journal of Science Education.* 29(9): 1163-1187.

Zohar, A. & Nemet, F. 2002. Fostering students' knowledge and argumentation skills through dilemmas in human genetics. *Journal of Research in Science Teaching.* 39(1): 35–62.

Appendix 1
Designer Babies: Case Study

Writing Frame: Designer Baby

Writing frame with an SSI-based Scenario and guided questions (Designer Baby Ethical Dilemma)

An IVF clinic has recently been offering to produce 'designer babies' for parents. For just $10,000 the clinic will check and, if necessary, change the parent's genes in order to produce the baby of their choice. Once selected, the baby develops normally inside the mother. The choice at the moment is limited to sex, intelligence, height and hair colour, but a spokesperson said that several other features would soon be available. All 'designer babies' are guaranteed free from identifiable genetic diseases.

Q. 1) Do you think this use of gene technology should be allowed?

     Yes   No

Q. 2) Why did you take this decision?

Q. 3) What are the reasons to support your decision?

Q. 4) What would the other person say if he/she disagrees with your decision?

Q. 5) If someone holds an opposite position with you, what would you say to convince him/her?

Q. 6) Under what condition would you change your decision?

Reproduced with permission from Venville & Dawson (2010). The impact of a classroom intervention on grade 10 students' argumentation skills, informal reasoning, and conceptual understanding of science.

Appendix 2
Content Specific Pedagogical Strategies

Teaching SSI-based argumentation – classroom processes

Intervention day	Content	Pedagogical strategy
Day 0	Pre-test. Designer baby case	Brain storm, recall of previous knowledge, interactive lecture, structure of cell video.
Day 1 (One period)	Recap structure and function of various organelles of a cell	
Day 2 (One period)	Nucleus (ultrastructure and function), structure of chromosomes	DNA song, power point slides to explain the ultrastructure of nucleus, chromatin network, nucleolus etc
Day 3 (One period)	Structure of chromosomes (variation in chromosomes number, morphology, euchromatin, heterochromatin, ultra-structure, giant chromosomes	Modelling to demonstrate the structure of chromosomes, human karyotype using low cost materials.
Day 4 (Two period)	Structure of DNA, Alleles- Dominant and recessive genes- Homozygous and heterozygous chromosome- genotype and phenotype.	Interactive lecture to explain the double helical structure of DNA, nucleotide. Modelling using commercial model of DNA. Group activity develop DNA strand through strips of nitrogen bases, sugar and phosphate molecules. Role play to show dominant and recessive genes expression. Case study of John: inheritance of dominant characters.
Day 5 (Two periods)	Replication of DNA. Transcription & translation, protein synthesis, genetic code & codon. Role of rRNA, mRNA & tRNA	Interactive lecture using videos to show replication, trans and translation of message into protein.
Day 6 (Two periods)	Sex linked inheritance (sex chromosomes, inheritance of X-linked genes, inheritance of Y-linked genes, X-Y linked genes.	Interactive lecture to explain inheritance of X-linked and Y-linked inherience of genes Case study: thalacemia
Day 7 (Two periods)	Modern gene concepts (introduction of gene, cloning, gene regulation and gene expression. Transmission of genetic material through different	Video watch Group work to sort strips related to germline or somatic cell therapy and give reasons

	agents (viruses, liposomes, heat shocks, bacteria etc). Germline Vs. Somatic cell therapy Mechanism of gene recombination, DNA repair, splicing. Point, frame shift & substitution mutation.	Video watch
Day 8 (Two periods)	What, why and how of SSI. Argumentation: a pedagogical strategy to teach SSI (highlighting the importance of valid evidence to support claim) Toulmin's Argumentation Pattern (TAP): introduction and practice Smoking should be banned in the restaurants	Interactive lecture and Pair work Power point presentation to explain different components of TAM Group work to classify given evidence for and against a given claim (e.g. smoking should be banned in big restaurant)
Day 9 (one period)	Toulmin's Argumentation Pattern (TAP): Practice Huntington Disease case (Zohar & Nemet, 2002)	Explicitly defined and provided examples of the parts of an argument specified in TAM (i.e. claims, data, warrants, backing, qualifiers and rebuttals). Discussion and listening to each other's arguments was encouraged in whole-class, and small-group discussion where facilitators played an important role in leading these discussions.
Day 10 (one period)	Toulmin's Argumentation Pattern (TAP): practice Cystic Fibrosis Case (Kolarova, Hadjiali & Denev, 2014). Do you think this use of gene technology should be allowed? Yes/No Write as many reasons as you can to explain your answer.	(debate to take position on) CPs were encouraged to generate claims individually about the target SSI followed by group discussions facilitated by the teacher. Finally, they shared their arguments in the whole-class set-up, teacher wrote statements on board. CPs analysed selected examples of written argumentation in light of TAM.
Day 11 (one period)	Hollywood star case	Small group discussion based on writing frame to document their argument about Hollywood star case scenario. Finally, they shared their argument with the whole class. CPs analysed selected examples of written argumentation in light of TAM.
Day 12	Post test: Designer Baby case	

Appendix 3
SSI-based Argumentation Process: Exemplifying Teaching Learning Process with Teacher's
Role as Facilitator

Argument process	Teacher facilitator role	Examples from classroom
Talking and listening	Encourages discussion	Yes, you are on right track. First identify your position. Are you in favor of somatic or germ line gene therapy?
Knowing meaning of argument	Exemplifies argument	Good, now you are making an explicit rebuttal against the opponents' counter claim. So, you are saying that by inserting the desired gene in the cells of the embryo (in utero therapy) the child would acquire desired characters.
Positioning	Encourages ideas	Your warrant is actually your strong belief. Good! You are providing data to think of different views to make a stronger argument.
	Value different position	Once germ line gene therapy is allowed how would you control its misuse? Think on these lines as well.
	Encourages positioning	Gene therapy is often questioned due to the ethical and moral dilemma. As a genetics student, how would counter argue it?
Justifying with evidences	Provide evidences	Think of more data to justify your claim.
	Prompt justification	… but retro virus could revert to wild type and may cause a disease to mother. So, would you still support the use of virus as a vector.
	Plays the devil's advocate	What if you are Mariam's father, would you like to know whether she is a carrier of Huntington gene?
Constructing argument	Uses writing frames	Hypothetical situation on 'Hollywood star gene cloning' and providing writing frames with some guiding question.
	Gives role to students	Use language frame to help students build opinion and reasons. Use debate organizer.
Counter-arguing /debating	Encourage debate by defining for and against positions	How would you rebut the counter argument made by the other group?
		If you are a genetic councillor, how would you refute people concern that the retro virus may revert and cause disease in the child or mother body?
Reflecting argument process	Ask about the mind-change	Do you think you can change the mind-set of people with genuine reasons? Could you apply argumentation in your daily life decision-making?

Note: The codes for facilitator's roles are adapted from Dawson & Venville (2010) and Bhutta & Anwar (in process).

Appendix 4

Analytical Framework for Assessing the Structure of Argumentation

Toulmin Argumentation Pattern (Toulmin 1958, 2013).

Levels	Descriptions
Level 1	Claim (statements, conclusion, proposition only)
Level 2	Claim, data (evidence supporting the claim) or warrant (relationship between claim and data)
Level 3	Claim, data/warrant, backing (assumption to support warrant)
Level 4	Claim, data/warrant, backing and qualifier (condition under which claims are true)
Level 5	Claim, data/warrant, backing, qualifier and counter claim (an argument that contrasts with a person's own theory)
Level 6	Claim, data/warrant, backing, qualifier displaying and extended argument with rebuttal to answer a counter claim.