A Framework for Socio-scientific Issue based Pedagogy

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Abstract

Socio-scientific Issues (SSI) based pedagogy has been internationally recognised as one of the most effective pedagogical strategies to ensure meaningful engagement of learners in science education discourse so as to promote scientific literacy. SSIs are real life contextual scientific issues which are often open-ended, and can be controversial involving multiple viewpoints stemming from the social, political, economic, ethical and environmental perspectives. SSI not only promotes scientific literacy but also critical thinking, socio-scientific reasoning as well as other 21st century skills in learners across all grades and stages. However, SSI based approach is not easy as the teacher needs to be aware of the complexity of issues and should also have the ability to bring in the multiple perspectives so as to enable the learners to comprehend and appreciate various dimensions. In this backdrop, the present paper discusses the importance and possibilities of positioning SSI in pre-service science teacher preparation. Insights developed from a design-based intervention in pre-service teacher education are discussed. In order to promote preservice science teacher's socio-scientific reasoning, an SSI based module was designed and implemented. Delving into the analysis of this pedagogical approach of engaging pre-service teachers in SSI, a framework for SSI based pedagogy in science classroom at all levels is proposed. Four aspects of this framework designed by the authors—SSI unit, teacher, learner and the learning environment are elaborated.

Keywords: Socio Scientific Issues (SSI), Socio Scientific Reasoning (SSR), Science Education, Teacher Education.

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Introduction

Socio-scientific Issues (SSI) refer to socially relevant scientific issues comprising of complex, real-world problems that have significant societal implications. Socio-scientific Issues (SSI) pertain to real world problems that are usually open-ended, could be controversial and have an ethical component (Sadler, 2004; Sadler and Zeidler, 2005). These issues can be looked at from different vantage points and have no single solution. Some examples of contemporary SSIs are—climate change, genetic engineering, designer babies, cloning, nuclear power plants, waste management, animal testing for medical purposes, plastic ban, multipurpose dams and most recently the issues associated with COVID-19 Pandemic.

Internationally, SSI is widely recognised as an open-ended pedagogy in science teaching at all levels as it contextualises science by placing it within social issues and provides opportunities to the students for an exploration of multiple perspectives, and to enable them to negotiate and strive towards resolution. While the traditional approaches in science education tend to examine issues in a decontextualised manner, the SSI based discourse gives opportunities to students to develop reasoning and analytical skills by engaging them in personally relevant, controversial scientific topics with social ramifications. In the last two decades, Socio-scientific Issues based discourse in science education has impacted scientific literacy significantly (Zeidler et al., 2019). SSI promotes scientific literacy through four facets—"Nature of Science, discourse issues, cultural issue and case-based issue" (Zeidler, 2014).

In the recent years, there has been a growing recognition of the importance of incorporating socio-scientific issues (SSI) based pedagogy in teacher education programmes though the researches in the Indian context are at a nascent stage. This pedagogical approach offers numerous benefits, such as fostering and enhancing scientific literacy apart from developing critical thinking and preparing the future educators to address the challenges of an increasingly complex world.

Moreover, the issues involve ethical, economic, political and cultural dimensions, thereby making them ideal for interdisciplinary pursuit—a thrust emphasised in recent policies, such as National Education Policy (NEP) 2020. Review of literature in science education has revealed that using SSI based pedagogy in teacher education increases content knowledge (Pedretti, 2003; Zohar and Nemet, 2002), and can serve as effective context to help students understand about various aspects of the nature of science (Khishfe, 2012). However, using SSI based approach is quite challenging as the teacher not only needs to be aware of issues but should also have the ability to bring in multiple perspectives, and enable

the learners to comprehend and appreciate various dimensions. It has been found that many times teachers are uncomfortable in dealing with the controversies surrounding the issue and exhibit anxiety in adopting SSI as a part of their pedagogy (Topcu et al, 2010). Research also indicates that pre-service teachers though eager to implement SSI based pedagogy, have anxiety about integrating the same in their classrooms (Kapici, Iihan 2016).

In order to use SSI effectively in the classrooms, teachers need to have the necessary pedagogical knowledge as well as skills. Hence, the teacher education programmes should include various aspects of teaching SSI to help Pre-service Teachers (PSTs) acquire necessary content knowledge and pedagogical skills to address controversial socio-scientific issues in the science classroom. PSTs' understanding and negotiation of SSI is not only important for their personal choices and decisions but also for their professional journey as a teacher, since they will teach such topics in their future classrooms to develop scientific literacy in their learners.

Review of Related Literature

Early researches on SSI based learning have been associated with increased content knowledge (Zeidler and Keefer 2003), increased understanding of nature of science (Zeidler, 2002, Khishfe 2012), ethical sensitivity (Sadler and Zeidler 2009) and argumentation. Later, researches have focussed on developing Socio-Scientific Reasoning (SSR) as the important outcome of SSI based pedagogy. Sadler et al. (2007 and 2019), proposed SSR as a construct to understand and explore the reasoning practices associated with 'negotiation' and 'resolution' of SSI.

The five dimensions of SSR as proposed by Sadler et al. (2007 and 2019) are:

1. Complexity: It refers to the ability to perceive and reason through the complexity inherent to SSI.
2. Inquiry: It refers to the ability to recognise the information that is not available regarding an issue as well as the ability to consider ways in which that information may be generated.
3. Perspective taking: It refers to the ability to analyse an issue and potential solutions from the perspectives of different stakeholders.
4. Scepticism: It refers to the ability to identify potential sources of bias that may influence information or the presentation of information about an issue or potential solutions.
5. Affordances and limitations of Science: It refers to the ability to determine how scientific knowledge and processes may contribute to the resolution of an SSI and to recognise dimensions of issue that cannot be addressed by Science.

Numerous research studies (Barab, Sadler, Heiselt, Hickey, and Zuiker, 2007; Dolan, Nichols, and Zeidler, 2009; Pedretti, 1999; Sadler et al., 2007; Sadler et al., 2011; Sadler, Romine, Stuart, Merle-Johnson, 2013) in the area of Socio-scientific inquiry based discourse in classrooms have focussed on different learning contexts for students to develop an understanding of Socio-scientific inquiry and reasoning. However, there is inadequate research about the role of SSI in teacher preparation as well as school education in India (Kaushik, Chunawala and Chari, 2022; Raveendran and Chunawala, 2013).

Pedagogy courses in teacher education programmes do not adequately address these issues and are unable to prepare the pre-service teachers to teach SSI effectively in their classrooms (Kalyani and Sharma, 2019). Moreover, pre-service teachers lack the content knowledge itself pertaining to crucial Socio-scientific Issues (ibid). In order to prepare future teachers to teach SSI in the class, it is important to first engage the teachers in the deliberations of SSI. This implicates a strong need to address these issues in pre-service teacher education programmes.

Methodology

Keeping the above conceptual frame of SSI, SSR and the need for pedagogical discourse rooted in Socio-scientific Issue based pedagogy, a need was felt to work out a framework for the same. The present autoethnographic research study employed the author's personal experiences and insights as a practitioner in combination with a systematic review of existing literature to develop a comprehensive model for socio-scientific reasoning for science education. This qualitative methodology rooted in interpretative framework is characterised by its' reflective and iterative nature, emphasising the integration of practice and theory to address real-world educational challenges. Before dwelling upon the framework, it is important to briefly describe the action research undertaken by the author that paved way for the framework. The methodology and findings of the research briefly described have been documented in another research article (Kalyani, 2021).

After an exhaustive review of the literature which included peer-reviewed articles, books, and conference proceedings and keeping with the spirit of 'action research', concerted interventions were done with 43 pre-service students of third year of Bachelor of Elementary Education Programme over two academic sessions of one year each (Kalyani, 2021). The research aimed to explore as to what extent PSTs' reasoning on 'complexity', 'inquiry' and 'multiple perspectives' developed after participating in classroom discussions and activities

in an SSI-focused module. Since the curriculum of the programme did not categorially mandate importation of SSI, a module was conceptualised. Data were collected through pre and post focus group discussions, interviews, reflective journals, student presentations and written reports. Autoethnographic methods were utilised to document personal experiences and reflections as a teacher educator.

After deliberation in the class and doing research the PSTs chose a variety of SSIs that were considered important to them given their context of Delhi. These included-genetic cloning, climate change, waste management, stubble burning, COVID-19, euthanasia, designer babies (Kalyani, 2021). The selection of issues for the PSTs was rooted in the belief that these students have to first themselves engage and experience 'perspective taking' (Kahn and Zeidler, 2019). It is through this immersive experiential process in which the PSTs choose contemporary issues, which resonate with them at a personal level that a meaningful engagement garnering multiple perspectives leading to 'pedagogy of discomfort' (Ohito, 2016) can be facilitated (Kalyani and Sharma, 2019). The PSTs then made a presentation to the entire group. Focus group discussions and individual reflective sessions were thereafter held, followed by assessment of the task and PST's understanding.

Table 1
Rubric for the Various Aspects of Socio-scientific Reasoning Levels

Level	Complexity	Perspectives	Inquiry
1.	Presents a very simplistic or illogical solution without considering multiple factors.	Unable to carefully examine the issue.	Unable to recognise the need for inquiry.
2.	Considers pros and cons but ultimately frames the issue as being relatively simple with a single solution.	Assesses the issue from a single perspective.	Presents unclear suggestions for inquiry.
3.	Construes the issue as relatively complex due to lack of information.	Can examine a unique perspective when guided.	Suggests a plan for inquiry focused on the collection of scientific or social data.
4.	Perceives general complexity of the issue based on different stakeholder, interests, and opinions.	Assesses the issue from multiple perspectives.	Suggests a plan for inquiry focused on the collection of scientific and social data.

The rubric used for assessing development of SSR as a part of the action research is depicted in Table 1.

The PSTs were engaged through a variety of teaching and learning activities during the SSI-focused module. Classroom discussions and group activities were found to be highly effective for PSTs' development of Socio-scientific reasoning. The discussion on Socio-scientific Issues including the pros and cons in terms of gaining multiple perspectives through presentation of information and discussions have significantly impacted PSTs' Socio-scientific reasoning. The group activities provided an opportunity for the PSTs to engage in decision-making processes and helped them in developing reasoning on Socio-scientific Issues. The PSTs were able to gain essential critical thinking skills that requires the ability to distinguish and discern scientific information from pseudo-scientific information as well as honing their skills of presenting key arguments and negotiating their perceptions in the light of counter-arguments presented. Working on SSIs helped pre-service teachers to evaluate scientific argument from multiple perspectives namely economic, socio-cultural, ethical and environmental aspects. Also working on their chosen SSI helped pre-service teachers, modify some of the views on Nature of Science as the SSI provided an authentic context to look at the issue from multiple perspectives and how socio-cultural determinants influence scientific research (Kalyani, 2021).

The study found that PSTs' reasoning significantly changed after participation in classroom discussions and activities. The PSTs were able to understand the complexity associated with the Socio-scientific Issues and could examine them from different perspectives. While exploring various aspects of Socio-scientific Issues, they used multiple information from both primary sources (interview with people, experts, stakeholders, scientists, doctors) as well as secondary sources (media reports, archival reports, newspaper articles, data reports) to justify their claims. When it came to position taking and decision making, they realised that in some cases, information explored by them was not sufficient to make an informed decision and further research was needed to come to a conclusive decision.

The analysis of the data emerging from the action research described above was further subjected to thematic analysis. Initial coding was performed to categorise data into themes related to SSI. These themes were refined through iterative reviews and cross-referencing with the author's experiences and the literature. There after, the identified themes were synthesised to develop the SSI framework for successful implementation of SSI based pedagogy at all levels of science

education as presented in this paper. Though this framework is derived on the basis of work done with PSTs, it has been postulated in order to facilitate development of SSR at all levels of science education.

Implications for All Levels of Science Education: Proposed Framework for SSI-based Pedagogy to Promote SSR

The proposed framework for SSI-based pedagogy consists of four core aspects—SSI unit, Learner, Teacher and Learning Environment. These four aspects are depicted in Fig. 1, followed by a description of each aspect.

SSI Unit as Core Aspect of SSI-based pedagogy

The first step towards SSI-based pedagogy for development of SSR is choosing a socially as well as a personally relevant, age-appropriate issue, which can be used to engage the learners in multiple perspectives. The issue could be central to curriculum but it is important to situate it in the authentic context

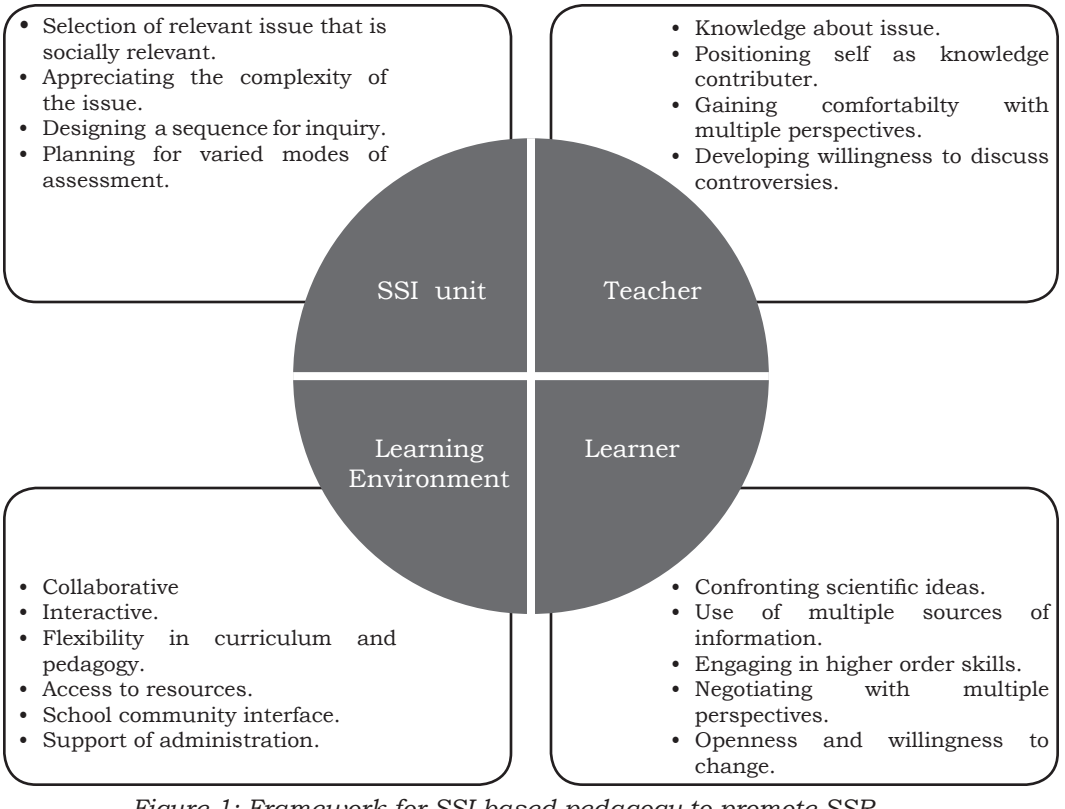

Figure 1: Framework for SSI-based pedagogy to promote SSR

of the learners. It is crucial that the classroom transaction begins and is centred around the issue rather than at the end of discourse or instruction. The prevalent discourse in several classrooms as well as textbooks has been to present case studies or examples of how the content is related to the real-world problems at the end of the class or chapter, respectively. For instance, a science textbook may present the social and ethical issues related to genetic engineering or Genetically Modified (GM) Foods after the introduction, and an explanation of the concept. The key point distinction here is not to superfluously weave the social relevance of the issue with the scientific basis but to position the issue as a socio-scientific one as posited in SSI-based pedagogy.

SSI-based pedagogy is grounded in providing real world contexts to give opportunity to the learners to navigate the social, economic, environmental, political and ethical dimensions of the issue. For example, the issue of genetic engineering raises the questions of whether and to what extent can humans 'intervene' with occurrences in nature; is it morally right to do so and whose right is it; what is considered 'best' and why should that be considered. These questions can also lead the students to inquire around the issue from a Darwinian perspective.

The next step involved after choosing the relevant SSI, is designing the sequence or plan for SSI-based instruction. This involves choosing learning experiences, group activities and planning for assessment. Scaffolding for student engagement in higher order practices for development of SSR is a crucial element in the transaction. The scaffolding can be structured to support learners to analyse multiple perspectives as they work to identify their own positions on a controversial issue. Another important aspect is providing a culminating experience through authentic assessments, which can be in form of self-assessment, peer assessment, presentations, reflective writing, role-play, project report and service-learning project. This provides the learners not only a platform for exchange of ideas and perspectives but also to integrate their learning with real world issues.

Hence, for successful implementation of SSI-based pedagogy in the classroom, the SSI unit:

- Should be selected carefully as a real world issue considered relevant by the learners.
- Should be addressed by appreciating the complexity of the issue.
- Needs to be sequenced in order to delve into an inquiry into the issue.
- Needs to incorporate planning for varied modes of assessment that are authentic.

Teacher as the Core Aspect of SSI-based Pedagogy

The second important aspect in successful implementation of SSI-based pedagogy is the teacher. An essential teacher attribute is familiarity and comfort with the issue around which the classroom transaction is planned. The teachers should be familiar with the political, social, economic and ethical dimensions of the issue chosen, and in a position to help learners in navigating through the complexities involved in perspective taking. Since SSI-based pedagogy is inherently built around an open-ended issue, it is difficult to predict the direction of classroom discussions. Hence, teacher should be in a position to deal with the uncertainty that might surface during the teaching-learning processes. They have to develop comfort with the uncertainty of the outcome of their planning and the multiple perspectives that would come up during the classroom discussions. Some perspectives that surface could be quite contradictory to the personal beliefs held by the teacher and the teacher should be able to deal with them by positioning in open-ended discussions. An open-mind and flexibility are key characteristics the teachers should possess along with an ability to be consistently reflective. All this entails that teachers become co-learners along with their students. For successful implementation of SSI pedagogy, it is essential that the teachers do not posit themselves as authority in the classroom. The teachers need to be honest about their limitations as possessors of knowledge and be willing to position themselves as knowledge contributor.

To sum up, for successful implementation of SSI-based pedagogy in the classroom, teachers need to be:

- Familiar with various social, economic, political, ethical and environmental dimensions of the issue.
- Open for the multiple perspectives which would emerge in the classroom discussions.
- Comfortable with bringing up and discussing the controversies in the issue.
- Ready for the uncertainties in the teaching-learning processes.
- Open-minded to consider a variety of perspectives.

Learner as a Core Aspect of SSI-based Pedagogy

Learners plays an important role as SSI is primarily a learner centric pedagogy that gives opportunity to learners to explore, research and present their perspectives. The entire discourse of SSI pedagogy values learners' opinions and perspectives, and is aimed at promoting SSR and other 21st century skills, such as critical thinking, co-operation and collaboration. As the learners are given opportunity to engage in higher

order practices like argumentation, reasoning and informed position taking, they should be ready to confront scientific ideas related to the issue. The learners should be prepared for a discourse different from traditional science classrooms and willing to take responsibility for their learning process. In this way, the SSI-based pedagogy is robustly situated in a socio-constructivist perspective that lays emphasis on the abilities of the learners to construct knowledge and make meaning.

Rooted in this pedagogical approach in SSI-based instruction, the learners are involved in data collection from multiple sources, and in analysing the same from varied perspectives and vantage points. As mentioned before, the SSI-based pedagogy aims to develop SSR skills, such as inquiry, perspective, scepticism, affordances in the learners. The pedagogy involves group and collaborative work, and willingness to consider others perspectives. For instance, if the SSI instruction is centred around climate change, various groups are encouraged to view climate change from multiple perspectives and accordingly formulate a research plan. The learners learn to analyse, evaluate and synthesise information from various disciplines in this process. This multifaceted approach encourages the learners to consider diverse perspectives, weigh evidence, and make informed decisions—a skill set that is crucial for addressing the complexities of both science and society. The learner experiences also involve negotiations and position taking, where they support their arguments on the basis of evidence-based research and data.

To sum it up, the learner experiences in SSI pedagogy involve:

- Engagement in higher order skills like reasoning, argumentation, critical thinking, informed and ethical decision-making.
- Promotion of SSR skills.
- Data collection and analysis from multiple sources and negotiating varied perspectives.
- Group and collaborative work.
- Position taking and gaining comfortability with changes in perspectives.
- Engagement with various aspects of nature of science.

Learning Environment as Core Aspect of SSI-based Pedagogy

Classroom environment plays an important facilitative role in successful implementation of SSI. The classroom environment subsumes the norms, and expectations necessary for implementation of SSI pedagogy in classroom setting and positioning it in the formal curriculum. As SSI pedagogy is different from traditional science pedagogical approaches, the classroom environments call for high engagement of both learners and teachers, in congenial and collaborative manner. In that sense, it

places high expectations on students and teachers.

Teachers and school administration have to create non-threatening, and facilitative environment for students so that they can freely express their perspectives without any fear and reservations. In SSI-based instruction, students often have to discuss controversial issues like cloning and to have meaningful dialogue, it is important that students and teachers feel safe, respected and valued. The classroom environment should facilitate for group work, and this needs teachers and students to be sensitive to the diversity in the class. The voices of marginalised needs to be respected in the classroom.

Another important aspect is support of school administration and community. Administration should support and encourage teachers using SSI-based pedagogy, and also allow flexibility in curriculum and assessment procedures so as to accommodate SSI in the formal transaction. Also, school and teachers should be aware of issues of local community and be ready to negotiate with community for SSI discussions in case of disapproval. In this connection school community interface and linkages is advocated. While discussing the issues of local community SSIs, such as stubble burning, waste management and plastic ban, it is important to respect sentiments of local community and at the same time provide platform to bring in other perspectives. Curriculum, and policymakers should give importance to SSI-based content in curriculum and assessment procedures. Teachers might be reluctant to develop or implement SSI-based lessons in the classroom when they find it having no place in the formal curriculum and assessment.

To sum it up, for successful implementation of SSI-based pedagogy for developing SSR in students, the learning environment should:

- Be collaborative and interactive.
- Be enabling towards respect and safety.
- Support and encourage SSI in the classroom.
- Make provisioning for resources to facilitate multiple perspectives.
- Provide flexibility to teachers to adopt SSI-based pedagogy.
- Cater to the needs and interests of local community through selection of issues, and thinking of authentic solutions.
- Develop strategies for strong community linkages.

Conclusion

Incorporating Socio-scientific Issues based pedagogy in teacher education is a transformative approach that not only enhances the professional development of future educators but also prepares them to meet the evolving needs of the educational landscape. By fostering critical thinking, enhancing scientific literacy, promoting interdisciplinary

collaboration, cultivating ethical decision-making and preparing for active citizenship, this pedagogical approach equips teachers with the skills and mindset necessary to navigate the complex intersection of science and society. As we continue to grapple with global challenges, educators trained in socio-scientific issues based pedagogy play a crucial role in shaping a future generation capable of addressing and contributing to the resolution of complex societal issues.

An effective and successful implementation of SSI-based pedagogy in elementary classrooms and development of SSR at all levels entails various aspects. A key component of this implementation is the teacher who needs to be adequately prepared to transact this pedagogical approach. To adequately prepare the teachers, it is imperative that the teacher education programmes should provide due space in the curriculum to incorporate SSI-based pedagogies. Specifically the science curriculum can be centred around socio-scientific issues and provide plenty of opportunities to the prospective teachers to engage in higher-order thinking processes, like critical thinking. Pre-service teachers and learners should have opportunities to engage in experiences like argumentation. The classroom environment needs to be supportive, collaborative and respectful in order to effectively facilitate these experiences. External factors, such as the school environment and the expectations of the administration, and the community can to a great extent influence how teachers and students deal with controversial issues in their classrooms.

The framework presented above is suggestive rather than prescriptive and is not intended as a step-by-step guide for implementation of SSI-based pedagogy. Though this framework is derived from the insights developed during the engagement of pre-service teachers in SSI-based pedagogical discourse, it can be used for all levels of science education. In-service teachers can use this framework to incorporate the aspects in their pedagogy while using SSI. This framework can be used by curriculum designers to effectively incorporate and integrate social issues with science content. Further research can be done to explore this framework for conceptualising and exploring various features of SSI-based instruction both in pre-service teacher education as well as school education. The framework can be used by various stakeholders to facilitate implementation of SSI-based pedagogy in science education discourse to promote scientific literacy.

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