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Research Article

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Promoting Socioscientific Issue-based Science Education – Finding Opportunities in Assessment

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ABSTRACT

There have been attempts to integrate assessment with teaching to enhance learning. In this study, we have attempted to use assessment as a strategy to foster socioscientific issue (SSI)-based learning. The available research suggests that teachers have a positive attitude towards the incorporation of SSI-based discussions in their classrooms simultaneously stating challenges like limited time, rigid syllabus, exam pressure, unavailability of related resource material, and intellectual demand on the part of the teacher as well as students, etc. We argue that 'guided assessment' as a pro-learning assessment approach could be used to promote SSI-based learning in the face of challenges. This paper describes and explores the efficacy of the 'guided assessment' task included in an SSI-based learning module developed on issues related to groundwater. This module was trialled with thirty secondary science students belonging to the lower socioeconomic background. The data related to the 'guided assessment' task was analyzed qualitatively using socioscientific sustainability reasoning framework developed by Morin et al. (2014) and we found that the 'guided assessment' strategy facilitated students through questioning and provided opportunities to reflect on themes crucial to decision-making. The findings also revealed the impact of peer interactions on decision-making skills of students. Based on this intervention, we propose that teachers can use such an assessment strategy to make their SSI-based instruction more efficient and effective.

Keywords: Guided assessment, pro-learning assessment, socioscientific issue-based instruction, student reflection

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INTRODUCTION: BACKDROP OF THE STUDY

The science curriculum developers have been struggling to develop a school science curriculum that fits well with the diverse interests and aspirations of all students, those who aspire to enrol in higher STEM studies and those who choose otherwise (Millar, 2014). Despite numerous initiatives in diversifying science curriculum design for all, school science courses continue to focus on disciplinary knowledge and practical skills (Hodson, 2003; Osborne & Dillon, 2008; Tal & Kedmi, 2006) either neglecting science-technology-society/socioscientific issues (STS/SSIs) perspective or addressing it superficially (Fensham, 2016).

Hodson (2003, 2008) attempts to address this gap by advocating 'critical science education' (CSE) perspective that views science in its social, political, and ethical context and is oriented towards socio-political action. CSE demands the inclusion of democratic practices within and beyond science classrooms to include voices of marginalized sections of society in issues related to S&T to promote a stance against racism, casteism, gender discrimination and other forms of oppression and facilitate social activism and citizenship (Schenkel et al., 2019). Zembylas (2005) argues that CSE involves learning experiences as per students' interests, which focus on social and political context of science targeted at the empowerment of students and leading them to act and think critically (Barton, 2003).

In India, the national curriculum framework (NCF-2005), recommended exposure to issues at the interface of science, technology, and society' (NCERT, 2005, p. 48) yet science textbooks, which are the main (and often, the only) source of transacting the curriculum (Kumar, 1986), majorly focus on disciplinary content knowledge with the socioscientific perspective just as an add-on at a few places (Raveendran & Chunawala, 2015). A content analysis of NCERT (2005) science textbooks indicated that limited attention is paid to STS and socioscientific perspectives, which results in limited opportunities for students to critically reflect on these issues and position themselves in agentic ways during the discourse (Kaushik, 2020).

Critical Science Education & Socioscientific Issues-Based Approach

Deliberating on SSIs has affordances to promote CSE by bringing forth veiled interest groups, diverse standpoints, and marginalized voices. It also has the potential to enable students to explore and understand social, political, and economic aspects of issues related to S&T and encourage them to take socio-political actions (Bencze et al., 2012; Hodson, 2008). SSI discussions can enable students to integrate scientific knowledge and practices with other forms of expertise and

help them understand and be vocal about issues of injustice in society (Schenkel et al., 2019).

SSIs are described as contentious, multi-faceted; real-life social issues that are conceptually linked to S&T and have ethical and moral dimensions (Zeidler et al., 2005). By engaging with such issues, students can be helped to think dialectically and evaluate the various involved aspects critically, construct reasonable knowledge and thus develop critical awareness (Levinson, 2006). Such engagement also necessitates contemplating moral and ethical aspects of issues situated within social, political, and economic contexts in order to make informed decisions (Kahn & Zeidler, 2019). SSI-based instruction also equips students to analyse the information provided in media and hence develop media literacy and scientific temper (Dani et al., 2010). Through constant deliberations with SSIs, students may learn to recognize their role and agency to bring positive changes in the larger community.

In Indian curricula, SSI-based instruction also seems in line with NCF-2005 recommendation to adopt 'a pedagogy that is sensitive to diverse backgrounds of students such as gender, class, caste, and global inequalities and how they are situated within larger structures of power and raises questions of their existence, their rights to speak, and if, at all their knowledge is valued? (NCERT, 2005, p. 24).' It is directly in line with the some of the objectives of science education stated in NCF-2005 such as to enable students to relate to the environment (natural environment, artefacts, and people), local as well as global, and appreciate the issues at the interface of science, technology, and society and to view science as a social enterprise. It is also aligned with the vision of the National Education Policy (NEP)-2020 (NEP, 2020) promoting multidisciplinary and holistic learning as SSIs are inherently multidisciplinary and require holistic approach in their deliberation (Zeidler et al., 2005).

Since SSI-based instruction can be effective in promoting active citizenship, we developed an SSI-based learning module on groundwater–a widely known and contextually relevant topic for Indian students. The overexploitation of groundwater is posing an existential threat to many communities, making this a serious environmental and sustainability issue. Eilks (2015) suggested SSI-based science education as an effective approach for 'education for sustainable development'. He argued that SSI-based instruction goes farther than many other context-based curricula and adds relevance to current societal debates. It focuses on learning how various dimensions (social, political, and economic) of sustainability can be actually discussed and evaluated in society.

The available research suggests that teachers have a positive attitude towards the incorporation of SSI-based discussions in their classrooms. However, they also state challenges faced, such as, limited time, rigid syllabus, exam pressure, unavailability of related resource material, intellectual demand on the part of the teacher as well as students, etc. (Pitpiorntapin & Topcu, 2016). Another major issue faced by teachers while adopting some new teaching-learning strategy is of 'assessment'. Any formal learning experience consists of curriculum, pedagogy, and assessment (Osborne & Dillon, 2008). The available literature related to SSI-based science education is mostly focused on the first two and less on assessment. While there are many challenges to incorporating SSI-based lessons in regular science classrooms, we need to exploit all possibilities to provide students opportunities to experience SSI-based learning. In this paper, we discuss the design of the 'guided assessment' task, which is part of SSI-based module on ground-water related issues. The module begins by providing students the big picture of this issue through relevant media articles. The assessment task intends to assess students' learning, identify gaps in their understanding and, also, guide them to think from a socioscientific perspective. We understand that such interventions are not directly used for summative assessments but are quite essential for teachers to promote SSI-based learning. We argue that this task could be used to promote students' learning in SSI-based lessons.

Assessment and Learning

Research has demonstrated that assessment processes focused on measuring learners' achievement in subject matter are not effective in promoting learning and do not do justice to learners' potential (Butler, 1997; Yan & Brown, 2021). Rather such assessment propagates competition among students and makes low achieving students feel inferior (Black et al., 2004). Recognising the interdependence of learning and assessment, the focus of assessment is gradually shifting from measuring how much a student has learnt to assessing how a student can learn better. There have been attempts to integrate assessment with teaching to enhance learning. According to Allal and Ducrey (2000), the primary goal of assessment is to determine response of diverse learners to instruction, whether the instructional processes are enhancing learning, and how on this basis instructional processes can be assessed and improved.

One such a perspective on assessment is 'dynamic assessment' (DA), a pro-learning form of assessment where the focus is on improving learning by promoting interactive collaboration between the learner and instructor. According to Cotrus and Stanciu (2013), DA involves embedding interactions within the assessment to gauge learner's responses and ability to profit from this interaction. They also pointed out that one of the significant characteristics of DA is mediation; learners are provided mediation at different stages of different cognitive tasks and strategies to master the tasks. There are many different approaches to DA, which aim to assess learners' hidden potential and capabilities in a process-oriented, diagnostic, and flexible manner. DA has roots in the Vygotskian concept of zone of proximal development (ZPD), which is proposed to be the difference between what a child can do autonomously and what she can achieve by the assistance of more knowledgeable persons (Vygotsky, 1978). DA is also rooted in the Feuerstein's concept of 'mediated learning experience' (MLE), which refers to 'human interactions that generate the capacity of individuals to change, to modify themselves in the direction of greater adaptability and toward the use of higher mental processes' (Feuerstein et al., 1991). In simple words, a mediator plays a pivotal role in the cognitive development of the individual by making the interaction between the individual and the environmental stimuli more meaningful.

Another body of research focused on 'assessment for learning' or 'formative assessment' (FA) is also based on the Vygotskian concept of ZPD. According to Black and William (1998), 'assessment for learning' is any assessment that primarily focuses on promoting students' learning instead of ranking or certifying competence. Such assessment becomes FA when feedback is used to adapt the teaching to meet learning needs. Black et al. (2004) further argued that adding FA to context-based approach also affects students' achievement positively and stimulates feedback between students and teacher. It provides opportunity for collaboration between teachers and students and peers. Such collaboration can help create a supportive environment where

students can explore their ideas and listen to others and understand their standpoints.

According to the NCF-2005 document, the purpose of assessment in Indian schools is to improve the teaching-learning process and materials (NCERT, 2005, p. 72); it states that 'the role of assessment is to gauge the progress that both learner and teacher have made towards achieving the aims that have been set and appraising how this could be done better. Opportunities for feedback, leading to revision and improvement of students' performance, should constantly be made available in class' (NCERT, 2005, p. 75). The NEP-2020 also calls for transformation in the assessment system to shift focus on FA (NEP, 2020, p. 106). It recommends developing 'regular adaptive assessment' similar to DA to help teachers regularly evaluate each student's progress and provide accurate feedback and individualized learning plans for students (NEP, 2020, p. 61).

Drawing from the concepts discussed above, we designed an SSI-based module on issues related to groundwater (discussed later). Since, SSI-based modules tend to be complex and come with additional challenges we tried to create ample opportunities for the students to practice necessary socioscientific skills as well as media literacy through this intervention. Moreover, since DA demands establishing an environment, where students' responses can be continuously gauged and used in improving pedagogic processes adding to the intellectual demand on teachers, we focused on designing an assessment tasksheet in our module (our intervention). This sheet provided students an opportunity to practice the SSI-based reasoning they learnt during module implementation and was useful in identifying areas where students need help. The assessment task was designed in such a way that the instruction was embedded within the task to guide the students to reflect on the themes and strategies crucial to the decision-making process in SSI-based contexts, Hence, we coined the term 'guided assessment' as students are provided with cues in the form of questions to 'guide them'. The designed intervention is discussed briefly in the next section.

STUDY DESIGN

Research Questions

Identifying 'assessment' as an area demanding attention, we focused on designing 'guided assessment' task as an attempt to infuse assessment with instruction to aid SSI-based learning among students. We aimed to address the following research questions:

1. In what ways do students express their views when engaging with an environment-related SSI?
2. How does 'guided assessment' help students in their decision-making process?

Participants and Setting

The participants in this study were 30 students of grade 9 studying in a local government-aided school in Mumbai. Majority of the students belonged to families with a low socio-economic status and lived in substandard areas in community housing. Most students had experienced water-related issues, such as limited or no government supply of potable water, water contamination, purchasing water from private vendors, sewage issues, etc.

The language of instruction in the school was largely Marathi (language of the State), but students participating in this study were from the English section of grade 9. These students were able to read science textbooks in English; however, they were more comfortable with Marathi and Hindi language while conversing. Students were familiarized with the purpose and focus of the research study and what was expected from them. The students who volunteered for the study were provided consent letters to be signed by their parents. These students were called to our neighbouring Center for Science Education after school hours twice a week for two weeks. Each session was two to three hours long and included a half an hour break. Students were provided with writing and drawing materials, such as notebooks, pens, pencils, chart papers, markers, etc.

Class Intervention

Description of the SSI-based module: Groundwater-It's in danger, so are we!!!

For the purpose of this study, an exemplar SSI-based module on groundwater was developed as 'groundwater' is a recurring theme in Indian science curricula (Kaushik, 2020). The module was aimed at enabling students to

(1) critically analyse news articles related to the SSI with the aim of understanding different perspectives and the societal aspects of the issue,

(2) identify and understand the scientific concepts involved,

(3) become aware of the ethical concerns and complexity of the issue,

(4) do a risk assessment while deciding, and

(5) conceptualize some actionable plans to deal with the issue.

The groundwater module was spread over four sessions, details of which are discussed in **Table 1**.

Description of the 'guided assessment' task

As discussed previously, this assessment task was designed to encourage 'pro-learning assessment' culture in class where instruction is infused with assessment. The objectives of the assessment task were to explore how students reflect on a given situation on their own; to guide them to examine the situation critically from different

Table 1. Description of groundwater module

Session	Task details	Expected learning outcomes
Session 1	Let's read the articles	Introduction to different aspects of groundwater-related issues such as groundwater scarcity, groundwater contamination, relation between groundwater & surface water contamination, & gender disparity due to water scarcity through newspaper articles.
Session 2	Let's understand the science behind it!	Identification & understanding underlying scientific terms & concepts, for example, groundwater, water-table, aquifers, aquitards, groundwater contamination, plume, concentration, bio-magnification, etc. using aquifer model.
Session 3	Let's unpack the issue!	Identification of different stakeholders & analysis of issues (identified from articles) from different perspectives.
Session 4	Group discussion on assessment task	Deliberation on given SSI and making an informed decision.

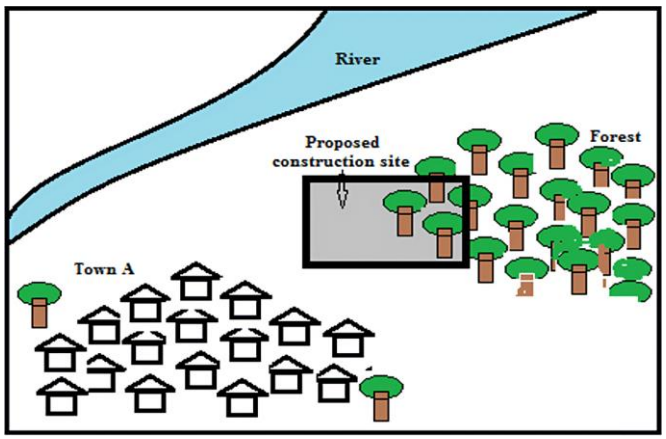

Figure 1. Situation provided to students (Source: Authors' own elaboration)

perspectives and make an informed stand; and to identify the areas where students need support for instructional purpose. The task focused on promoting 'how to think' instead of 'what to think'.

While designing the assessment task, we paid attention to the fact that students need to reflect on the discussions we had during the implementation of the module, for example, the relation between surface water and groundwater, ways of contamination, impact on different people/communities, roles and responsibilities of common people and government, etc. With the limited or no experience of engaging with SSIs previously, such opportunities for reflection provided to students are important and valued in SSI curriculum development.

The assessment task consisted of two activities. In the individual activity, students needed to deliberate on the given situation and take individual stances. In the group activity, students discussed their views with peers and made collective decisions. The purpose of including both the activities was so that each student is engaged with the issue and also gets an opportunity to practice the necessary social skills required to make collective decisions- as adults do in a democratic society. The assessment task involved a hypothetical situation (refer to **Figure 1**).

Students were informed that 'a company wants to build an oil refinery unit at the proposed site for which they need government approval. In return of land acquisition, the company offers to help in the development of town infrastructure and offers jobs to the local community. The oil refinery needs a large amount of water for industrial processing.'

The assessment task consisted of four questions: (1) 'How would the company's proposal affect the lives of residents of town A?' This question aimed to explore how students think about the impact of the construction of the new refinery on the town. The next question pertained to the environmental aspect and students were asked: (2) 'Some environmentalists have raised some concerns over the company proposal; what the environmentalists' concerns could be?' Students were next asked to think about social aspects by the question: (3) How would this proposal affect the life of different people living in that town? Finally, students were asked to (4) Decide whether the company should be permitted to build the plant at the proposed site, or they would like to formulate some regulations for the company at the time of granting permission.

Data Collection

Students were provided with the assessment tasksheet as homework to be completed on their own. All the instructions, descriptions and questions in the assessment sheet were in English as well as Hindi and these were read out by the instructor and explained to the students so that the questions were clear to them. This discussion was restricted to questions alone. Students were given time to read the assessment task and raise queries, if any, and instructed to submit the completed tasksheets. After students submitted the assessment tasksheets, these were examined, and some discussion points were identified. In the group discussion activity (session-4), students formed four groups of seven-eight students. They were given 30-40 minutes to discuss their views (against and for the construction of refinery plant) among themselves and make a group decision. Then, each group was asked to present their decision (five-seven minutes) and five minutes were given to other groups to ask questions and for them to defend their decision. Student groups also made concept maps or flow charts, etc. depicting environmentalist concerns, the stakeholders, and suggestions, etc. Students' responses in the assessment tasksheets, concept maps/charts and audio-video recordings were then analyzed.

Method of Data Analysis

The situation given to the students had a very significant sustainability aspect, so we used the socioscientific sustainability reasoning (S3R) framework developed by Morin et al. (2014) to characterize the students' responses. This framework seems exhaustive in including all the possible dimensions of the SSI-based discussions along with the sustainability aspect.

Description of socioscientific sustainability reasoning framework

The S3R framework proposes six dimensions to assess students' responses to SSI issues, which are problematization (understanding the complexity), interactions (complexity in the socio-eco-systems and its dynamics), knowledges (articulate the various dimensions of scientific and other forms of knowledges), uncertainties and risks (conditions when knowledge is valid and the repercussions of the knowledge), values, and governance (social institutions' and their participation into regulations).

In this framework, four different levels are specified for each dimension; level 1 referring to just one right answer; level 2 involves recognising multiple positions, values, knowledges, level 3, identifying many elements and recognition of a need for integration of knowledges, aspects, values, and participation of different stakeholders; and finally, level 4 envisioning knowledge as complex, plural, contingent, uncertain, and conditional on context (Morin et al., 2014).

The data was analyzed qualitatively. In assessment tasksheet, most of the students responded in Marathi and Hindi, and few in English. These responses were first translated in English and cross-checked by two fellow researchers who were well versed in the above languages. These responses were read carefully and categorized into themes corresponding to questions asked in the assessment tasksheet. For example, for Q1 in assessment task, we looked for whether a student is discussing only positive or negative or both impacts of setting up the refinery. Further, within the themes, we identified the responses that corresponded to the six dimensions of S3R framework and analyzed further to identify the level these responses belonged to. For example, if a student tried to problematize the given situation but focused only on the negative or positive aspects, then such responses were included

in the problematization dimension corresponding to level-1. Preliminary analysis of the data was done and discussed among authors. After having consensus over the process and the themes identified, the analysis was completed. No major conflicts were observed.

The group activity data (chart papers and recordings) were analyzed descriptively. The recordings were listened carefully many times and then the relevant portions were transcribed and analyzed using the same framework and coding process.

RESULTS AND ANALYSIS

In this section, analysis of students' individual responses gathered on the guided assessment tasksheets is presented followed by discussion of students' collective responses obtained through the group activity. The students' stance on Q1-Q4 are presented quantitatively in **Table 2**.

Analysis of Students' Individual Responses

Q1-Students' (initial) attitude towards the company's proposal

In the first question, students were asked how the company's proposal would affect the lives of the residents of town A. This question was aimed at assessing students' initial stand on the given issue. A total of 24 students attempted this question. The various dimensions considered by the students in response to this question were 'environmental pollution and water shortage (10)', 'people's health (eight)', and 'economic impact (19)'[1]. **Table 2** indicates the students' initial stance on the company's proposal question (Q1).

About half of the students (12 of 24) were positive to the company's proposal of building an oil refinery. Some detailed responses were:

> Towns people will get jobs, and there will be roads ... and town will develop (S21).

> People will get jobs, compensation for their lands, concrete roads in the town along with other facilities (S24).

It appeared that students formed their opinion based on the superficial information provided in the assessment task. For example, most responses highlighted the economic benefits to the townspeople in the form of jobs and improved infrastructure that the company promised to offer. Students at this point may not have recognised the complexity of the situation and adopted a linear approach focussing on benefits that the townspeople would have and did not attempt to problematize the situation.

Six students, however, opined that the company's proposal will have only negative impacts on the lives of the townspeople. These negative impacts were mainly environmental (air and river) pollution that would occur due to the chemicals discharged from the refinery, its impact on human health and water shortage. For example, one student wrote, as follows:

> Refinery will need a lot of water for cooling and heating; it will release chemicals into river, which will affect people's health adversely, especially those who use this water for drinking, dish washing, and laundry (S6).

The information that oil refinery needs a large amount of water *for cooling and heating* was not directly provided to students. Their engagement with the SSI may have required them to look out for more information or access some information they already had. They also anticipated that the refinery would release waste into the river and cause health issues. Another one of these six students also thought of the harm that implementing this proposal could cause to the forest by mentioning the issue of tree cutting.

Such responses illustrate students' attempts to explore the dynamic interaction between various systems (in this case, environmental, economic, and social). They explored how the proposal would harm the environment, which in turn would have a negative impact on the different aspects of the lives of the townspeople. However, these responses also indicate the unilateral approach of students, again focussing solely on the negative aspects.

Two students discussed both positive and negative impacts. Their responses included both economic benefits to townspeople and the negative impacts on the environment and people's health if the proposal is accepted. They tried to problematize the issue by viewing it from different perspectives. This can be demonstrated by the following response:

Table 2. Quantitative analysis of students' responses to Q1-Q4

Q1-Impact of company's proposal		**Q2-Environmentalists' concerns**		**Q3-Stakeholders identified**		**Q4-Final decision on the proposal**	
Students' responses	No.	Students' responses	No.	Students' responses	No.	Students' responses	No.
Only positive/good impacts	12	Water/river pollution	23	Common people	13	No	17
Only negative/bad impacts	6	Air pollution	15	Unemployed people	8	Yes	-
Both good & bad impacts	2	Harm to trees & plants of forest	11	Employed people	3	Yes but with some conditions	9
Beneficial if company obeys some rules	4	Water shortage	14	Farmers	3		
		Crop contamination	7	Environmentalists	13		
		Animal health	4	NGOs	4		
		People's health	15	Govt employees/politicians	3		
				Research centers	2		
				Animals	5		

Responses distribution across levels of reflection				
Levels of reflection	**Q1**	**Q2**	**Q3**	**Q4**
Level-1	n=12	n=0	n=0	n=0
Level-2	n=6	n=11	n=3	n=3
Level-3	n=4	n=13	n=12	n=14
Level-4	n=2	n=0	n=3	n=9

[1] Numbers in bracket indicates number of students citing mentioned dimension

> People will get jobs and they will get oil easily, but factory waste may make them sick; chemicals from factory will cause harm to them (S16).

Four students opined that the proposal could be beneficial to townspeople if the company followed some rules:

> They (company) should give a guarantee that they will not harm the environment; they will give some oil to people; they will not discharge their chemical waste in river and people should ensure that company does not discharge its chemicals in river; they will plant trees; if company agrees to this then it should be given permission (S13).

Here, students' thought of some actions that can be taken to ensure the maximum benefit to the community. Such responses indicate students' awareness of the significance of regulatory processes that include citizen participation in balancing the various interests (social, economic, and environmental).

Q2-Students' perception of environmental impact of company's proposal

The second question asked students to think about the concerns that could be raised by environmentalists. This question was aimed at making students think carefully and comprehensively about the environmental impacts and bring to their' attention the interconnectedness among systems. Students' responses on the question regarding the concerns of environmentalists (Q2) are presented in **Table 2**. All students tried to explore various environmental impacts and their implications on the different aspects of the lives of townspeople. Seven major environmental concerns raised by the students were noted: water/river pollution, (23), air pollution (15), harm to trees and plants of forest (11), water shortage (14), crop contamination (seven), animal health (four), and people's health (15)[1]. Some responses were, as follows:

> Company will take water from nearby river and may cause air and water pollution, which may be harmful to people's health (S2).

> Water may get polluted, which may contaminate crops; and since the factory needs a lot of water, there may be a water-shortage for people in town (S5).

> Trees will be cut, which will harm environment, and then animals will not have a place to live so they will enter the town (S13).

These responses indicate students' efforts to explore connections between different systems, i.e., how disturbance in one system will cause disruption in another (cutting of forest trees would lead to wild animal invasion issue in nearby town, etc). Students' responses also exposed gaps in students' understanding of environment, for instance, one students compared vegetation with the environment; he said, 'if there are no trees, then *there will be no environment'* (S-14).

Some students also expressed concerns over contamination of the crops grown using the contaminated river water and its impact on people's health. They mentioned that this could harm farmers business and may lead to increased cost of agricultural products.

> Chemical waste from the refinery will get mixed with river and contaminate it, people from town A use this water for drinking and for agricultural purpose. It will make them sick and will make the crops inedible. Farmers business will get harmed, and people will not get to eat, this will be the cause of environmentalists concern (S11).

Students also mentioned issues of water shortage and groundwater depletion. They probably used the information provided to them regarding the water usage of oil refinery and thought about its impact on availability of surface water and groundwater and extrapolated its effect on lives of townspeople.

Regarding environmentalists' concerns, students not only talked about obvious consequences like river and air pollution but also tried to look for the extended impacts like crop contamination, animal issues, increased cost of agricultural products, etc. This demonstrates students' awareness of the interconnectedness and dynamicity among different systems. It can be inferred from students' responses that they not only used the understanding of scientific knowledge but also their understanding of other forms of knowledge like social and financial (economics) aspects.

Q3-Identification of different stakeholders

The third question asked students to assume the role of residents of town A and write their opinion about this proposal. This question was aimed at assisting the students to identify the stakeholders affected by this decision, e.g., an employed person or an organisation. 18 students responded to this question. The stakeholders identified by the students were: common people (13), environmentalists (13), unemployed people (eight), animals (five), NGOs (four), employed people (three), government employees/politicians (three), research centers (two), and farmers (three)[1]. Some of the students' responses as different stakeholders are presented below. One student wrote from the environmentalist's perspective. She penned, as follows:

> Factory should not be constructed at that site because chemicals from the factory will pollute the river and groundwater and there will be adverse effects on the forest because trees and plants are getting water from the ground and because of chemicals they will die … as we know all living being dependent on each other and if one dies, for example, trees then it affects many more. And drinking chemical contaminated water may have a bad effect on people's health and they may die, and the factory will also cut trees (S25).

Another student responded from an NGO representative's perspective suggesting the need of critical scrutiny to make an informed decision:

> Where will wastewater be discharged, how much water will be needed for the refinery per day, where should it be constructed, how many trees will be needed to be cut for the refinery (S20).

Some students speculated how deforestation could lead to wildlife entering in human settlements in search of food and shared the perspective of common people and environmentalists.

Students also brought in the perspective of government employees who will have to undertake the responsibility of ensuring that refinery plant follows the rules and does not cause air and water pollution

otherwise they may lose their jobs. They also shared the possibility of malpractices for example, the statement, *'the politicians will make money' (S20)* reveals that they are considering the possibility of corruption. Moreover, they identified the need for research centres, which will regularly monitor the quality of the air and water, and independent regulatory bodies or organizations (like NGOs) to monitor potential harm. Students' responses reveal their understanding of different stakeholders' perspectives and the complexity of the issue.

Q 4-Students' decision on company's proposal

The fourth question required students to decide whether the company should be allowed to build the oil refinery plant at the proposed site. Most of the students (17) were against the construction of the refinery plant whereas some (nine) were in favour of constructing the plant if the company agreed to follow laid down conditions, while no student was in favour of the proposal as it was proposed.

The arguments that students raised against the construction of the refinery plant were mostly related to environmental degradation and its effect on human health. They also argued against cutting down of forest area and harm to animals and birds that it would cause. Students' responses revealed the value they attach to the environment. A few students opined that people should not be lured by the possibility of jobs and other benefits offered to them. Students appeared to have done some risk-benefit analysis while making their decision. For example, one student wrote, as follows:

> Although people will get a job, they will be troubled a lot; they will have troubled breathing because of polluted air; people may lose their lives and it may also affect forest trees adversely and if trees will be affected, it will cause harm to humans also (S4).

Students also expressed their concern for the farmers and their business:

> Refinery's wastewater will be mixed with river water and may cause danger to townspeople. Contaminated water may make people sick, as farmers use this water for irrigation, so crops grown will not be good and then people will not buy those, and farmers will have a loss (S11).

All the students who gave their consent to the company's proposal put forth some conditions for the company. They argued that the company's proposal will be helpful in the town development; however, there is a need for some rules to ensure that it does not harm the environment and townspeople. In formulating these rules and conditions, most students used their scientific knowledge as well as awareness of other sources of knowledge. Their responses revealed their concerns about the town, forest, river water, underground water and the well-being of farmers and other people in the town and also the people living down the river. Most students suggested formulating some regulations to deal with the chemical discharge from the refinery plant and a change in the location of the refinery plant, away from the forest and somewhere below the town. A few students also suggested that the company be asked to plant trees to compensate for the air pollution it may cause. One student opined that people should demand of the government to setup a unit to treat polluted water. Such responses reveal that students have some idea of the role of governance in sustainable development.

Comparing Students' Primary Responses to their Final Decision

We found that initially, most students were at level-1 (n=12) and level-2 (n=6) of the S3R framework, which means, at first, they only looked at the positive side of the proposal without problematizing it (level-1) or they were able to problematize the issue but did not attempt to assess both positive and negative aspects (level-2). They appeared to build their responses around the information provided to them in the assessment task. Only a few students showed reflection corresponding to level-3 (n=4) and level-4 (n=2). The students who were at higher levels of the framework brought out different aspects of the situation (level-3) as well as values and tried to explore possible ways, which can benefit society (level-4), for example, by proposing that people should ensure that the company does not pollute the water bodies by discharging chemicals into it (S13), etc.

As students navigated through Q2 and Q3, which required them to explore the environmental impacts and different standpoints, their responses became more reflective. While engaging with these questions, students reflected on the dynamicity and interconnectedness among different systems (social, economic, environmental), and how the proposal will impact different people differently. They also pondered on their personal and community values. **Figure 2** depicts one student's responses (S21) and how these evolved.

Overall, as we qualitatively analyzed students' responses to Q4, we found these to be more comprehensive. Many students showed the reflection of level-3 (n=14) and level-4 (n=9). Students explored

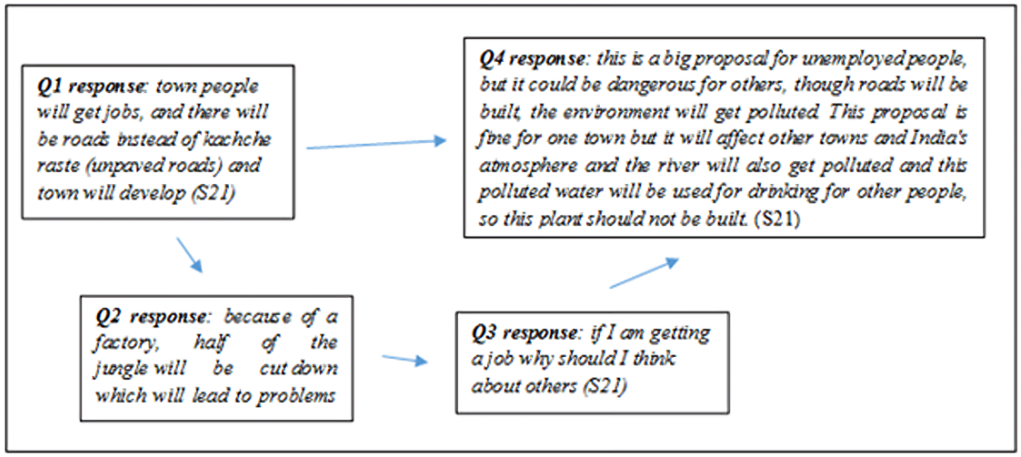

Figure 2. Student's responses (S21) to Q1-Q4 (Source: Authors' own elaboration)

positive as well as negative impacts that the company proposal will have on the environment and townspeople and attempted risk assessment. Most students finally decided against the construction of the refinery plant owing to the environmental destruction it would cause which would impact the lives of the townspeople as well as those living in the jungle. Students' responses reflected the value they attached to environment conservation (forest, its inhabitants and river). Finally, students who decided in favour of the construction of the refinery plant formulated some rules for the company and community people to follow and ensure that the company abided by those rules.

Students' Collective Responses from Group Discussion

In the fourth session, students were asked to discuss their responses with their peers in groups and make a small presentation. Students made concepts maps depicting environmentalists' concerns, and those of various stakeholders along with some suggestions. Most responses displayed on chart papers were similar to what they had expressed in the assessment sheets, but these were collective responses that included viewpoints of each group member. There were some instances of responses that were not included in any students' assessment tasksheets, and these are highlighted in this section.

For instance, during the presentation by group-1, a student from the audience asked:

> Why would there be a decrease in the oxygen level? (pointed out as one of the environmentalists' concerns).

The presenter gave the following explanation:

> Company will pollute the air by releasing harmful gases so there will be less oxygen (in air) and in water also, the release of chemicals can lead to decrease in oxygen level in the water and may harm the water animals.

Such responses by the students showed how SSI-based discussions unveil students' misconceptions and gaps in understanding of science content. Also, a query raised by one student, can trigger learning or curiosity among other students. Such instances indicate the potential of group assessment activities in promoting learning. Here, the process of learning became the social process.

This group activity also invoked students' emotions as they defended their stances. A student asked the presenter from group-3:

> Why are you concerned if trees are cut?

The presenter responded by using an analogy and comparing the situation with the issue of deforestation of the Aarey forest of Mumbai, which was being hotly discussed in the media at the time. The student said, as follows:

> When the government cut Aarey forest, we feel bad, so when the company will cut the trees for their factories, then people living in nearby areas will also feel bad.

These responses indicate that SSI-based discussions on issues relevant to the students invoke emotional responses, which can possibly lead to pro-environmental actions.

In the group presentation, the list of stakeholders identified by students was exhaustive. They included water animals, vehicle owners, and company representatives who were not included in the individual written assessment sheets. This suggests that collective learning is often more than the sum of individual learning.

None of the student groups was against the construction of the refinery plant, but each group presented some suggestions to minimize the environmental degradation and maximize the benefits for society. Most of these suggestions were proposed by students who were in favour of the construction of the plant if the company agreed to follow some rules. But in the group activity, these suggestions were discussed in detail. For example, if the refinery plant is to be built somewhere else to minimize the risk to river and forest, then where should it be and why? One group suggested that the plant should be built below the town away from the forest and nearer to the river; this way it would not cause any harm to the forest, and it will get the required water from the river. Also, people should make a committee to ensure that plant does not take more than the permitted quantity of water and does not pollute the river.

DISCUSSION AND CONCLUSION

Most available literature related to the SSI-based approach to science education focuses on assessing the effectiveness of SSI-based instruction in promoting science content knowledge, understanding of NOS, citizenship education, active participation, etc. through open-ended questionnaires and interviews (Bencze et al., 2012; Hodson, 2008; Levinson, 2006; Zeidler et al., 2005). There are a few instructional frameworks available that may help science educators in implementing SSI-based approach but the research on assessment tools to promote students' learning of SSI-based contexts is scarce. In this study, we presented the design of a new adaptive guided assessment strategy and have tried to explore its strengths to promote learning in SSI-based education. Since, SSI-based approach demands students, at times, to be skeptical and deliberate on the issues from multiple perspectives, explore various connections, evaluate different standpoints, and then make an informed stance (Bencze et al., 2012), while designing the SSI-based learning module and specifically while designing the guided assessment task, we tried to create spaces for students to practice these skills. Such guided assessment task design can be a good resource for teachers worldwide who are willing to incorporate SSI-based approaches in their classrooms.

We found that in their initial responses, most students were in favour of the company's proposal and their arguments were based on the information provided to them. However, as they proceeded through the rest of the questions and probes, many students shifted their standpoints. These changes in students' responses indicate the mediations (Cotrus & Stanciu, 2013) students might have experienced during discussions while critically thinking about extended information, peer views, etc.; and point towards the significance of scaffolding that students need especially during the early stage of SSI-based instruction where all stakes are not easily identified.

According to Sadler and Donnelly (2006), deliberations on SSIs expose students to multifaceted perspectives, which help develop critical thinking. The guided assessment appeared to be helpful in making students reflect on environmental and other standpoints, which is evident from the comprehensive students' responses to the final question. The students' responses had characteristics of socioscientific reasoning as conceptualized by Sadler et al. (2007), which include

(i) recognizing the inherent complexity of SSI,

(ii) examining issues from varied perspectives,
(iii) appreciating that issues are subject to ongoing inquiry, and
(iv) possessing skepticism in the examination of potentially biased information.

The subsequent questions provoked the students to think deeply and as result, students not only problematized the proposal but did so while making the connection between different systems and extrapolating the impact. The impacts mentioned were of river water pollution on groundwater, contamination of agricultural products, farmers' business, people and animals' health and increased price of fruits and vegetables. Student's demonstrated their skepticism about politicians and other government bodies who could be involved in malpractices during authorising permissions, supervisions, etc. at the time of approval of the proposal. This assessment exercise made use of all such issues mentioned by students and wove them back into the discussion. It provided students with the opportunity to explore the dynamicity and interconnectedness among various systems and to understand the significance of diverse components of the human and natural environment.

Our study suggests that scaffolding can help in the direction of promoting responsible and active citizenship, which is recommended as an important objective of implementing SSI-based education (Evagorou & Dillon, (2020); Ratcliffe & Grace, 2003). Students envisioned themselves taking roles and responsibilities of a common citizen in a democratic society when they suggested that people from the community should make sure that the company follows the rules, or the NGOs should take care of the environment.

This guided assessment strategy also provided us with a window into students' thinking processes, misconceptions, and their value systems. Deliberations with the SSIs (in the current task as well) requires one to reflect on values (Zeidler et al., 2005, 2019). For instance, in the given task, students needed to compare and contrast the economic benefits that the company would provide to the townspeople with the environmental degradation that it could cause; and many students valued the environment over economic benefits. We found that students had pro-environmental stances and according to Herman et al. (2018), students' engagement with such environment and sustainability-related SSIs (as used in the present study), which emphasize cultural, scientific, affective, and social justice dimensions could promote pro-environmental dispositions among learners.

Research studies (Herman, 2013) recommend FA to improve science teaching-learning process mainly due to its diagnostic properties. The present guided assessment task also served diagnostic purpose by revealing the gaps (or more appropriately considerations of missed aspects of ground water phenomenon in our context) in students' thinking processes, which could be useful in preparing remedial material and providing students feedback to improve their learning. For example, in their initial responses, most students were in favour of the company's proposal as they were primarily thinking about the benefits that townspeople would have if the refinery plant were constructed, whereas, later most students included possibilities of environmental destruction in their final decision making. Those who continued with their initial decisions are equally respected as they had fair chances to negotiate with peers and arrive at a final decision. The guided assessment provided students opportunities to reconsider their initial positioning, negotiate it by evolving information, and finally make more informed choices.

The literature shows that group discussions (if designed carefully) are effective in developing critical thinking skills among learners (Bennett et al., 2010; Brookfield & Preskill, 2012). The group assessment exercise provided opportunities to students to question as well as present rebuttals to arguments and reasoning. When the students were asked to discuss their views within the groups, students who took a stand against the construction of the refinery plant changed their decision to allow the construction of the plant if some regulations/conditions were met. This highlights the significance of practising collective decision-making where students can put forth arguments, learn other's viewpoints and try to convince each other and take collective decisions democratically. Such an assessment strategy provides prospects for not only individual learning but social learning as well, attempting to leave no students behind. Guided assessment also appeared to be effective in promoting a democratic decision-making process, which is considered one of the most important aims of SSI-based education (Evagorou & Dillon, 2020; Levinson, 2006; Zembylas, 2005)

While conducting the study, we found that a group of students took cognizance of stagnant water in their geographical area and decided to write a letter to the authorities. The group shared the letter attested by the local authority with us through WhatsApp. It was the same group whose member defended the forest in the given task comparing the issue with the deforestation of the Aarey forest of Mumbai–home for many endangered species of birds and animals in India. Research has shown that people who see themselves as connected to the environment are more likely to engage in pro-environmental behaviour and take actions for the wellbeing of the environment (Clayton, 2003).

In conclusion, we agree with Feuerstein et al. (1981) who argued that assessment should be ultimately regarded as a component of instruction, as 'an integral part of intervention and not as an end in itself'. We believe that guided assessment could be an effective strategy for promoting students' learning especially in the context of SSI-based instruction. Teachers can use such an assessment strategy to make their SSI-based instruction more efficient and effective for two main reasons; first, the assessment strategy provides students with an extra opportunity to exercise SSI-based reasoning and decision-making; and second, it helps teachers to diagnose gaps in students thinking processes and hence improves teaching-learning.

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