Towards an Understanding of Socioscientific Issues as Means to Achieve Critical Scientific Literacy

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In this paper, we make a case for fostering critical scientific literacy (critical SL) using socioscientific issues (SSIs) for students in the 14-20 age group at school and undergraduate level in India. To explicate the idea of how SSIs can serve as pedagogic resource to foster critical scientific literacy, we identify five SSIs related to controversial medical technologies from the Indian media and discuss these issues in terms of an elaborate theoretical framework proposed by Levinson (2006). Finally, we explore the possibilities of whether the Indian educational curriculum has space to accommodate SSIs by critically examining curricular documents at the school and the undergraduate level for the vision of scientific literacy and science-technology-society education that they advocate.

Critical Scientific Literacy

The term Scientific Literacy (SL) is a concept used to 'express what should constitute science education for all students' (Roberts, 2007). The term is contested politically and intellectually and multiple meanings have been attributed to it. Douglas Roberts (2007), in an extensive review devoted to discussing the meanings of SL identifies two positions that have 'come to represent the extremes on a continuum'. He terms them vision-I and vision-II. Vision I represents a view of SL that emphasizes the "cannon of orthodox science"- "products and processes of science itself" in the curriculum. Vision II advocates SL "through situations with a scientific component"- situations students are likely to encounter as citizens (Roberts, 2007). Roberts points out that "considerations other than science" are also emphasised in this vision of scientific literacy. In the vision I-vision II continuum, we position ourselves at the vision II end and advocate a critical scientific literacy. The concept of a critical scientific literacy is not new. Several science educators (Roth & Désaultels, 2002; Hodson, 2003) have advocated it. Weinstein (2008) defines critical scientific literacy as,

> " a certain scholarly and activist tradition rooted in dialogues between Marxism, Antiracism, Feminism, Queer Politics, Liberation Theology, and anti-colonialism—for starters—but also to a prior tradition both within science communities as well as "lay" spheres challenging science's embeddedness within the militarism and capitalism".

Critical SL advocates like Hodson (2003) envision a politicised science curriculum which enables students to understand that science and technology-related decisions are taken in accordance with particular interests of certain groups and are justified by certain values often "prejudicial to the needs of the poor and powerless". In effect, they advocate a conflict view of science education that seeks to question power relations and foster social justice concerns in the students. This vision of scientific literacy is shared by educators advocating feminist pedagogy (Mayberry, 1998) and Freirian science pedagogy (Santos, 2009). Santos (2009) illustrates what a curriculum devoted to critical science education would look like, by using the example of garbage disposal. While a conventional curriculum may focus on topics like chemical constituents of garbage and separation methods during recycling, a critical science education curriculum would primarily be concerned with the humanistic dimensions of garbage disposal like why there are people living in landfills and where they come from.

The importance of critical scientific literacy in developing countries has been stressed by some educators. (Kyle, 1999), in an article devoted to challenging first world hegemony in defining science education goals emphasises the need for social justice concerns that revolve around contextually relevant science-technology and society issues in developing countries.

Socioscientific issues (SSI) and critical science education

One way to foster the kind of scientific literacy envisaged in the previous sections is to engage students in SSI. Hodson (2003) argues that politicization of science education can be achieved by exposing students to real-world issues that have a science, technological or environmental dimension. SSI are "social dilemmas with conceptual or technological links to science" (Sadler, 2004) These are typically ill-structured, real world issues that are controversial in nature. The need to introduce SSI in the school and undergraduate curricula has been recognized by the international science education community as well as national curriculum documents in several countries (Zeidler & Keefer, 2003); (Hughes, 2000).

Different epistemological frameworks of understanding the science-society interface inform how different researchers understand the issue of negotiation of SSI. Levinson (2007) discusses these frameworks on the basis of how technocratic they are. Technocratic frameworks of understanding the science-society interface stress the importance of canonical scientific knowledge in negotiating the issue and see scientific experts as solely capable of arbitrating on it. In non-technocratic frameworks of science-society interface, the central role of science in resolving the controversy is not privileged and the science needed to negotiate the issue is seen as tentative and uncertain. Scientific knowledge may also be critiqued and challenged in this model. Sources of knowledge that resolve the controversy are seen to emerge from the needs of the participant and is interdisciplinary. Anecdotal evidence, local knowledge and socio-cultural world-views are valued. As critical SL advocates, we adhere to a non-technocratic framework of understanding the science-society interface.

Technology related SSI

Derek Hodson (2003) highlights the importance of using problems and issues related to technology in fostering critical scientific literacy. According to him, technology being “all pervasive” in the western world, the values surrounding them are constantly discussed in the print and visual media. In an article devoted to discussing science, technology and values, Allchin (1999) discusses how technologies can either raise new ethical and social dilemmas based on pre-existing values or challenge it more directly. He illustrates with examples of how technologies like hemodialysis and organ transplantation technology sustain the value of preservation of life or health but raise new values on equitability of access while technologies like the new reproductive technologies challenge values more directly by complicating the concept of parentage.

Hodson (2003) argues that it is therefore easier to see how socio-cultural context impacts technology and vice-versa than it is for science but he also underscores the fact that using issues related to technology “is not an argument against teaching science; rather, it is an argument for teaching the science that informs an understanding of everyday technological problems and may assist students in reaching tentative solutions”. He points out that a politicised science curriculum rejects the notion of technological determinism and students should be empowered to make choices on what technologies they will or will not use.

Fostering Critical Scientific Literacy Through SSI` Surrounding Controversial Medical Technologies

In this section, we identify five topical SSI in the Indian media which can be used with students of the 14-20 age group. These issues are such that they raise social justice concerns, value concerns and may require the use of scientific evidence for resolution. Some of these issues also raise questions on the validity of scientific perspective. Students can bring in personal experiences and alternative world-views to bear upon the issue.

All the five issues are related to controversial medical technologies. We use a framework suggested by Levinson (2006) to unpack these issues which can be examined at multiple levels. This framework is particularly useful because it is based on a non-technocratic model of understanding SSI and legitimates the role of different sources of knowledge in negotiating the issue. (Levinson, 2006) unravels the epistemological nature of SSIs and is perhaps one of the few frameworks that exist in science education literature that delves into this aspect. One strand of this frame-work that is relevant to our discussion is the detailed profiling of SSIs in terms of the Levels of reasonable disagreement (LoD) which makes explicit what is it at stake in a SSI in terms of evidence, values and world-views.

He discusses 9 levels of disagreement from which SSI can be examined. The direct role of evidence in resolution of the issue diminishes as we move from level 1 to level 9. Concomitantly, other aspects like difference between ethical premises, view-points due to personal experiences, indeterminacy of concepts and differences in world-views become the sources of contention than evidence. It must be noted that evidence may play a role in negotiation of issues at all these levels, but its necessity goes down as we move up the levels. This framework enables us to discuss the issues thoroughly at multiple levels. Table 1 is derived from Levinson's framework (2006) on LoD. Five contemporary SSIs related to certain medical technologies and concerns related to evidence, world-views and values in resolving them are discussed in the table.

The issue of paid organ donation involving live organ donors is controversial and has been discussed in the Indian media[1]. It raises questions on access, safety of donors and larger social justice questions of exploiting poverty (Phadke & Anandh, 2002). Scientific evidence on health risks for organ donors may be important on resolving the issue (Goyal, Mehta, Schneiderman, & Sehgal, 2002). Commercial surrogacy[2] raises similar questions on safety of the procedure for surrogate mothers and biological mothers as well as questions on social justice (Shah, 2009). Value positions on whether biological motherhood is such a valuable end in itself may also be debated. Scientific evidence on safety of procedures and success rate of IVF procedures may be important on taking positions on the issue.

The issue on ultrasound technology and disability is structured around a case that happened in India in 2008 - Popularly known as the "Niketa Mehta Case"[3]. This case initiated an almost non-existent debate in public forums on abortion as well as disability rights in the country. The abortion debate has in some sense been over-shadowed by the sex-selection debate in India (Madhiwalla, 2008). Madhiwalla (2008) discusses the complexities of the issue where the woman's right to a free choice on abortion may be challenged from the perspective of disability rights pitting the feminist and disability movements against each other.

Mid-2011, the "Aruna Shanbaug"[4] case opened up a debate on euthanasia of patients in a permanently vegetative state (PVS). Ethical differences on value of life and right to a life free of pain might be a matter to consider while resolving the issue. Scientific knowledge on nature of PVS state and its diagnosis may inform negotiation. A recent case[5] on sex change operation has opened up debate on gender and sexuality in the Indian media. Apart from the rights of the LGBT community to practise sexuality/gender of their choice, there are more fundamental questions on whether alternative expressions of sexuality need to be considered a 'disorders' and the role of science in legitimating this view (Levinson, 2010).

As it can be seen, there is no dearth of SSIs in the Indian media for students to discuss and debate in the classroom. Using Levinson's framework, key dimensions of these controversies can be parsed out and discussions can be initiated at each of the levels. Students can appreciate the complexity of the issues and employ different domains of knowledge in negotiating it. In doing so, they can also learn about the nature, strengths and limitations of each of these domains of knowledge in negotiating the controversy and the role of evidence.

Are We Ready for SSI in the Indian Science Curriculum? Articulating Concerns

To understand the issue of whether the Indian Science curriculum has any scope to deal with SSI in the manner we advocate to use it, we examine the National Focus Group's position paper on the *Teaching of Science* (National Focus Group, 2006) for its vision of scientific literacy and its advocacy for STS education. This position paper informed the National Curriculum Framework 2005 on which recommendations for textbook writing, both at the national and state level have been based. The position paper appears to advocate a vision I scientific literacy with emphasis on the learning products and process of science as evidenced in this statement:

> Facts, principles, theories and their applications to understand various phenomena are at the core of science and the science curriculum must obviously engage the learner with them appropriately (p.11, Position Paper on the Teaching of Science)

According to the position paper, the 'general aims of science education' should be understood in terms of 6 validities- cognitive, content, process, historical, environmental and ethical validities. Cognitive validity requires that the material be age-appropriate and within the developmental level of the child while content and process validities emphasize the need for factually correct content and appropriate training in the methods of the science. Historical validity requires that some history of science be included so that students appreciate how 'concepts evolve with time' and get acquainted with biographies of prominent scientists while environmental validity requires that the student "appreciate" issues at the interface of science technology and society. Ethical validity requires that student develop certain habits of the mind like honesty, freedom from prejudice and objectivity.

1 http://www.wired.com/medtech/health/news/2007/05/india_transplants_main?currentPage=all

2 http://www.nytimes.com/2011/10/05/world/asia/05iht-letter05.html

3 http://www.indiatogether.org/2008/aug/ksh-mtpchoice.htm

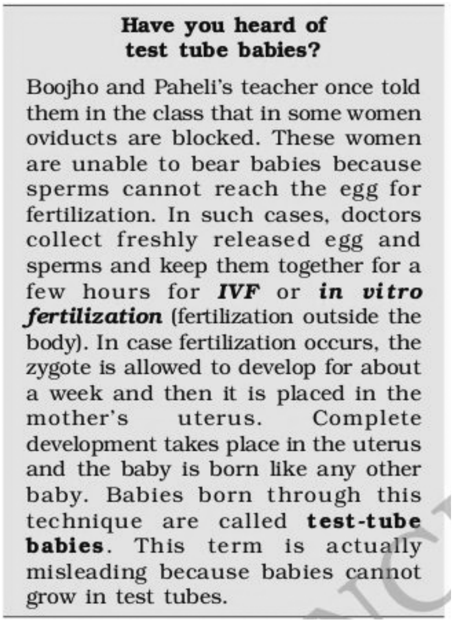
4 http://articles.timesofindia.indiatimes.com/2012-05-13/india/31689540_1_surgery-plastic-surgeon-gender

5 http://www.ndtv.com/article/india/aruna-shanbaug-case-supreme-court-rejects-euthanasia-plea-89894

Although a hierarchy in the importance of the validities are not stated, there is an implicit sense that the core emphasis is on content and processes of science.

This becomes obvious as we look at the prescriptions for science education at different levels. At the primary school level, the emphasis is on *environmental studies* which fuses both the science and social sciences. But from class VI onwards, the curriculum prescriptions emphasise content knowledge. At the higher secondary level, STS is relegated to the domain of co-curricular activities as evidenced by this statement,

"...Students should be encouraged to participate in debates and discussions on issues at the interface of science, technology and society. Though these would form an important part of the learning process, they should not be included for formal assessment" (p.16, Position Paper on the Teaching of Science)



Have you heard of test tube babies?

Boojho and Paheli's teacher once told them in the class that in some women oviducts are blocked. These women are unable to bear babies because sperms cannot reach the egg for fertilization. In such cases, doctors collect freshly released egg and sperms and keep them together for a few hours for ***IVF*** or ***in vitro fertilization*** (fertilization outside the body). In case fertilization occurs, the zygote is allowed to develop for about a week and then it is placed in the mother's uterus. Complete development takes place in the uterus and the baby is born like any other baby. Babies born through this technique are called **test-tube babies**. This term is actually misleading because babies cannot grow in test tubes.

Figure 1. Text box from the class VIII NCERT Science Textbook on test tube babies or IVF

Although the position paper acknowledges that the majority of students up to class X are not training to be professional scientists or technologists and that the science curriculum up to class X needs to prepare students to be scientifically literate to "develop awareness" about STS issues, there is no actual discussion on how these issues should be introduced. STS content is also marginalized in NCERT science textbooks. For e.g. Figure1 from the class VIII NCERT Science textbook discusses the technology of "Test tube babies" or IVF. There is no reference to surrogacy, which is an important aspect of IVF procedure around which several social and ethical questions have been raised. Questions regarding the safety and efficacy of the technology are not raised. The text also propagates the patriarchal myth that infertility is a problem of the woman. This manner of presenting controversial technologies is completely at odds with how a curriculum devoted to fostering critical scientific literacy would present it.

The undergraduate curricula in India tends to be highly specialized, emphasizing rigorous training in content knowledge and laboratory/field work in science subjects. The (Yashpal Commitee Report, 2009) emphasizes interdisciplinarity in the curriculum and exposure of science students to courses in humanities and social sciences, but STS as a subject is non-existent in most undergraduate science courses. Students who take up humanities, social sciences and commerce at the undergraduate level cease to engage in science after school. This trend of decreasing emphasis on STS education as we move up levels of education is in sharp contrast to other parts of the world where there is an emphasis on STS education at the secondary school, high school and undergraduate level (Zeidler & Keefer, 2003; Hughes, 2000).

SSI	Level 1/2	Level 3	Level 4	Level 5	Level 6	Level 8	Level 9
Paid organ donation through living donors	-Health risks for the donor -How is paid organ donation working out in other countries	Concerns related affordability to all and access if it is legalized	Is it ethical to use the poor's need for money to get them to sell organs?	Are the donors making a 'choice' to sell their organs? Is the choice free if it is motivated by poverty?	organ donors health at stake even if people are dying due to lack of availability of organs		Some people might be against commodification of organs
Sex change operations for transexual individuals	Medical risks associated with surgeries for transsexual adults		Right to belong to the gender of one's choice	Transsexualism- a lifestyle choice or a disorder?			Transsexualism is considered by some to be against the laws of nature
Ultrasound technology and its use in diagnosing disabilities	-Nature of disability: Lifespan, morbidity -Options available to accommodate the disabled (special schools, institutions other extant social welfare measures)	Role of the state and family in taking care of disabled patients	-Sanctity of life versus right to life free from suffering -Slippery slope question of whether the technology should be used against minor disabilities	Questions on interpretation of "Rights"- 'Right' to life or 'Right' to life free from suffering		People who have a disabled family member may have strong positions on the issue	A person could articulate a pro-life stand on account of religious/ cultural world-views
IVF technology and Commercial surrogacy	-Health risks for surrogate mother -success rate of IVF procedure -Health risks for biological mother	Concerns related to affordability to all and access	-Adoption versus Biological motherhood -Are poor women going to be exploited?	-What constitutes 'parenthood'? Does lending genetic material amount to parenthood? What about the role of the surrogate mother as a parent? -Are the surrogates making a 'choice' to rent their wombs?	Surrogate mother's health compromised even if infertile couple gets to have their own baby	An adopted person may have strong positions on the issue	A person might view the practice of commercial surrogacy as equivalent to prostitution and may object to it
Euthanasia of PVS patients	-Are PVS patients capable of thoughts? -How long do they survive? -What life support equipment are needed to support them?	Role of the state and family in taking care of PVS patients	Sanctity of life versus life free of pain	Questions on interpretation of "Rights"- 'Right' to life or 'Right' to a life free of suffering	Are PVS patients 'suffering'? (how do we interpret this when the patient is incapable of self-expression)	A person who has seen a close friend /family member suffering from comma/PVS state may construe the issue differently	A person could articulate a pro-life stand on account of religious/cultural world-views

Table 1. Description of SSI based on Levinson 's framework (2006)

Description of the levels in Table 1 (As discussed in Levinson, 2006):

Level 1- "Where insufficient evidence is as yet not available to settle a matter, but where such evidence could in principle be forthcoming at some point"

Level 2- "Where evidence relevant to settling a matter is conflicting, complex and difficult to assess"

Level 3- "Where the range of criteria relevant for judging a matter are agreed, but the relevant weight to be given to different criteria in a given decision is disputed"

Level 4- "Where a range of cherished goods cannot simultaneously be realised, and where there is a lack of a clear answer about the grounds on which priorities can be set and adjustments made"

Level 5- "Where the range of criteria relevant for judging a matter are broadly agreed, but there is dispute about the proper interpretation of a criterion or criteria, given the indeterminacy of many concepts"

Level 6- "Where there are different kinds of normative consideration of different force on both sides of an issue, and it is hard to make an overall judgement"

Level 7-" where there is disagreement about criteria relevant for judgement" (According to Levinson(2006), this category can be subsumed under level 9. Hence it is not discussed in the table above)

Level 8- "Where the differing 'total experiences' of people in the course of their lives shapes their judgements in divergent ways"

Level 9- "Where there is no agreement about whole frameworks of understanding relevant for judgement"

Concluding Remarks

We believe that there is a need to introduce SSI based instruction from the secondary school up to undergraduate level. At the school level, whether they should be introduced in the science curriculum or in the social science curriculum will need to be deliberated on. There could be integrated themes that cut across both the subjects involving teachers in cross-disciplinary collaboration. This would perhaps help teachers deal with the issue of communicating the complexity inherent in these issues. SSI based courses can also be introduced at the undergraduate level which could be open to both science and non-science students. This will enable non-science students to have a continuing engagement with science in a manner meaningful and relevant to them.

The authors of this paper are currently engaged in carrying out studies of how students in the 14-20 age group bring to bear different sources of knowledge in understanding the issues discussed in the paper. These studies could shed light on how curriculum material and classroom discussions can be structured to help students negotiate SSI and develop their sensitivity to social justice questions related to science and technology.

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