

Chapter 22

Socio-scientific Inquiry-Based Learning: Taking off from STEPWISE

Ralph Levinson and The PARRISE Consortium

22.1 Introduction

In the contemporary post-industrial world, where effects of neoliberalism and globalisation on education policy are becoming increasingly insidious (Ball, 2013), it is encouraging to see a resource such as STEPWISE,¹ which explicitly challenges underpinning social values and epistemologies of school education encouraged by a market adapted for extreme consumerism. STEPWISE provides not only encouragement for socio-political engagement but a theoretical framework that justifies the strategies adopted. For reasons discussed in Chap. 2, it is challenging for the STEPWISE philosophy to gain leverage in science school curricula. Those situations where STEPWISE has gained momentum perhaps emphasize the exceptional characteristics of pedagogy and democratic school structures where such practice is enabled. Enacting the STEPWISE philosophy cannot separate itself from the broader educational and social context. Science curricula in most post-industrial countries have outcomes based on meeting certain defined targets and a teacher

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¹STEPWISE' is the acronym for Science & Technology Education Promoting Wellbeing for Individuals, Societies & Environments. It is a theoretical and practical framework that organizes teaching/learning goals in ways that encourage and enable students to self-direct research-informed and negotiated actions to address personal, social and environmental problems linked to fields of science and technology. To learn more about this framework, refer to Chap. 2 in this book (and: www.stepwise.ca).

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culture that is underpinned by ‘presentism’ (Hargreaves & Shirley, 2009), a persistent focus on short-term measurable outcomes.

22.2 The Political Climate

Schools and their curricula do not exist in a socio-political vacuum (Apple, 2004). Science curricula, and their associated STEM agendas, have been particularly susceptible to political influences (Pierce, 2015). This can be seen, for example, in the 2012 curriculum reforms by the UK conservative government, which imposed greater prescription and focus on content (Vasagar, 2012). Added to this are political pressures generated from international comparisons through the PISA results where England was seen to do badly compared with the Asian tiger economies. “‘England needs a rocket under them to improve their PISA scores’”, says Minister for Education” (Baird et al., 2011, p. 140).

One of the reasons why there is such panic about achievement in STEM subjects can be seen in resources that privilege science, technology and engineering in higher education as well as in rhetoric that accompanies pushes towards the STEM agenda. Such rhetoric is couched in language of national economic competitiveness, human capital resource (Thomasian, 2011), supply and demand, high-end technologies and added values — together with ‘softer’ language of climate change and sustainability (Ravetz, 2005). The new science-society formulation of the EU, however, is ‘RRI’ (Research, Responsibility and Innovation): emphasises being on science *for* society and *with* society (Owen et al., 2009). Advancements in science and technology need not be detrimental to the planet or to human communality; on the contrary, with public participation and goodwill, technoscientific progress in a market-driven economy could, according to RRI philosophy, go hand-in-hand with technologies that can remediate some of the more harmful effects to environments. Such proposals need to be treated with caution, however, particularly in light of dismantling of welfare state policies in Europe, rise of free marketism and entrepreneurship, as well as the complexity of relations of technical expertise and lay knowledge and concerns (Jasanoff, 2003).

No one except an extreme Luddite (in fact there is a lot we can learn about collective bargaining from the Luddite movement and the political organisation in response to the introduction of labour-saving technologies) would gainsay that technologies can be enhanced for the public good. For those of us, particularly those born between the end of WWII and the 1960s, who live in the post-industrial world in relative affluence and employment, benefits of a highly developed science and technology base are manifest in vastly improved health, longevity, mobility, educational possibilities compared with our grandparents. But the problem is not that science and social egalitarianism are mutually contradictory; i.e., that science and technology are associated with markets and free enterprise, as opposed to fair distribution of goods. Despite attempts to exploit possibilities of digital technologies, for example, to address social exclusion and enhance social mobility little progress

has been made (Selwyn et al., 2001). One of the problems is the nature of the consumer-led and driven market that creates goods which harm social life, and a hyper-reality (Baudrillard, 1994) that is self-referencing. Social and material inequalities reduce social trust and drive consumerism; there is a correlation, for example, between a country's income inequality and low levels of waste recycling and high carbon emissions (Wilkinson & Pickett, 2010). When tracing back materials that give us so much value (e.g., superconductors, gems, rare metals) to their source (a problem addressed by STEPWISE), benefits of material progress for the affluent in rich countries need to be measured against material and social devastation caused to those in producer countries (Shiva, 2000).

Over the last thirty years in the UK and much of the industrialised world, there have been shifts through the 'Third Way' (Giddens, 2008) towards more overt neo-liberal discourses; the recent TTIP (Transatlantic Trade and Investment Partnership) agreements reflect the extent to which the EU treads carefully with global corporate giants. New information and social media technologies have accompanied these changes, which have also enhanced possibilities for, and economics of, globalisation. In terms of science, there have also been concomitant changes in the nature of citizenship, from one which was dependent on the goodwill of the state and scientific expertise to one which has become sceptical of expertise, and organising itself in new ways (Novas, 2006). STEPWISE's response to this problem is to enhance social empowerment through school science education (Bencze & Carter, 2011).

22.3 Socio-scientific Inquiry-Based Learning (SSIBL)

In this article, I discuss a framework for a European project (EU) that is influenced by philosophy associated with STEPWISE, namely an aspiration to social justice through authentic action, but which builds up from inquiry and citizenship through the EU formulation of RRI.

SSIBL The European Union has a broad commitment to Inquiry Based Science Education (IBSE) (Rocard, 2007). Inquiry-based methods have been shown to increase 'both children's interest and teachers' willingness to teach sciences' (p. 12). Much of IBSE funded by the EU to date has focused on developing scientific knowledge and procedures (in STEPWISE terms, Products and Skills Education) and has been broadly inductive. Pierce (2015) has described this separation of science from social and cultural concerns as 'purification,' which stems from a broader Enlightenment problematic.

Socio-scientific inquiry is challenging for teachers because it takes students to unexpected and unanticipated areas of knowledge. Some of the inquiries discussed below are similar to the kinds of activities proposed by STEPWISE. I am part of a consortium of science teacher educators in universities in Europe, with the acronym PARRISE (Promoting Attainment of Responsible Research and Innovation in Science Education) funded by FP7 ('FP7' stands for the '7th Framework Programme for Research and Technological Development' and is designed to respond to



Fig. 22.1 The components of SSIBL

Europe's needs in terms of jobs and competitiveness, as well as enhancing the global knowledge economy), developing inquiry activities in the context of Research, Responsibility and Innovation (RRI), Citizenship Education (CE) and Socio-Scientific Issues (SSI) (see Fig. 22.1).

Our project acknowledges importance of social participation: scientific research and production should be carried out *with* and *for* society (Owen et al., 2009). How this can be achieved presents political and structural challenges (von Schomberg, 2013) through 'anchor points' that are ethically acceptable, sustainable and socially desirable. Influences of political literacy; i.e. critical citizenship education on inquiry-based activities frame science inquiry within contexts of social and political questions, what we have termed SSIBL (Socio-Scientific Inquiry Based Learning). At the heart of SSIBL is researching a question aimed at improving local and/or global conditions, producing realisable outcomes through democratic processes, and drawing on scientific knowledge that may be recontextualised as part of this process. The inquiries should stem from the concerns and pre-occupations of the young participants, although scholars such as Laurent Humbel et al. (2012) recognise that social inquiries stimulated by controversy need to incorporate a pedagogical triggering mechanism, an 'element declancher'. Hence, part of the SSIBL programme at the scaffolding stage has much in common with apprenticeship activities in STEPWISE. In the next section, we describe some examples that reflect the spirit of SSIBL.

What SSIBL Activities Might Look Like Before depicting the SSIBL framework, below are a few examples to illustrate its philosophy.

22.3.1 Campaigning Against the School's Sugary Drink Dispenser

This account was given by a college principal and formed part of the evidence for the Valuable Lessons (Levinson & Turner, 2001) research study.

Senior management in a college for students in the 16–19 age range installed a drinks dispenser to raise money for extra-curricular activities. Noting the problem of a dispenser of high-sugared drinks in their college, a small group of students decided that the action by the school authorities was detrimental to the students' interests. Such drinks were deemed to be unhealthy and to inhibit concentration. They approached the Principal, asking for the dispenser to be withdrawn. The Principal refused, arguing that money raised by use of the dispenser helped to fund out-of-school activities and was used by many students.

The group then decided to collect as much secondary evidence as they could to buttress their argument and to campaign within the college for its removal. They brought their argument to the College Council, a representative student body, which decided that the dispenser was not in the college's best interests but to also form a group to find alternative ways to make good any losses incurred by the removal of the dispenser. The college management agreed to implement their decision and to work with them to find alternative ways to raise money.

22.3.2 Assisted Reproduction

This activity is based upon challenging representations of assisted reproduction (AR) often promoted by private clinics (Fig. 22.2).

Questions about AR are commonly-discussed in older age groups in secondary schools, aged 15+. Young adults are reaching an age where having children becomes realisable and many values of family and status are related to having children. AR is a medical resource that can enable a couple to have children, but problems as presented in schools are often conceptualised as medical ones: the biology of the couple's reproductive systems, and associated psychological problems (Reis, 2015). But these raise other 'hidden' questions.

1. Should AR be publically funded through the health service. What is health? Does AR come under the category of health? In some countries, AR may be positively encouraged through public health services for political reasons; e.g., population growth. In others, it may be very difficult to gain access to them.

Fig. 22.2 Use of images to promote raising questions (Taken from <http://www.dailymail.co.uk/news/article-2143184/Fertility-firm-appeals-Cambridge-University--girls-egg-donations.html>)



Would you help us start our family?

We long to be parents, but a rare genetic disorder that causes repeated miscarriages has prevented us. We are now looking for a real-life angel to be our egg donor.

If you are compassionate, kind, healthy and between 18 and 35 years old, could you help us?

We can imagine no greater gift than the chance to love a child.

Please contact:
alison@altruist.co.uk
 or call 0844 745 3033 / 01969 667875
www.altruist.co.uk/donors

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2. If AR is sought privately, this raises questions of social justice — a balancing of rights ('I have the right to spend my money to follow options open to me') as against egalitarianism and social cohesion ('why should advantages of embodied nature be available for some and not others?'). In a society where it is seen as desirable, or having status, to have children accessibility to this technology is, therefore, a political question. What about political, cultural and religious issues in extending these rights to same-sex couples?
3. Regulation of the fertility industry. Fertility clinics regularly advertise through media (see Fig. 22.2). How they represent themselves is open to critique. But how are they regulated against malpractice?
4. That technologies are available makes it important to understand risks involved. What information would we need to assess these risks?
5. What about ethical questions implicit in AR? Such a technology effectively makes selection of particular attributes possible. The most common is sex selection but also selection against or sometimes for particular disabilities; e.g. there has been a debate in the deaf community about selecting *for* deaf children (Mand et al., 2009).
6. Poorer countries have become suppliers of cheap womb labour and services; e.g., egg provision. Globalised economies, reproductive tourism (www.eggsploitation.com).

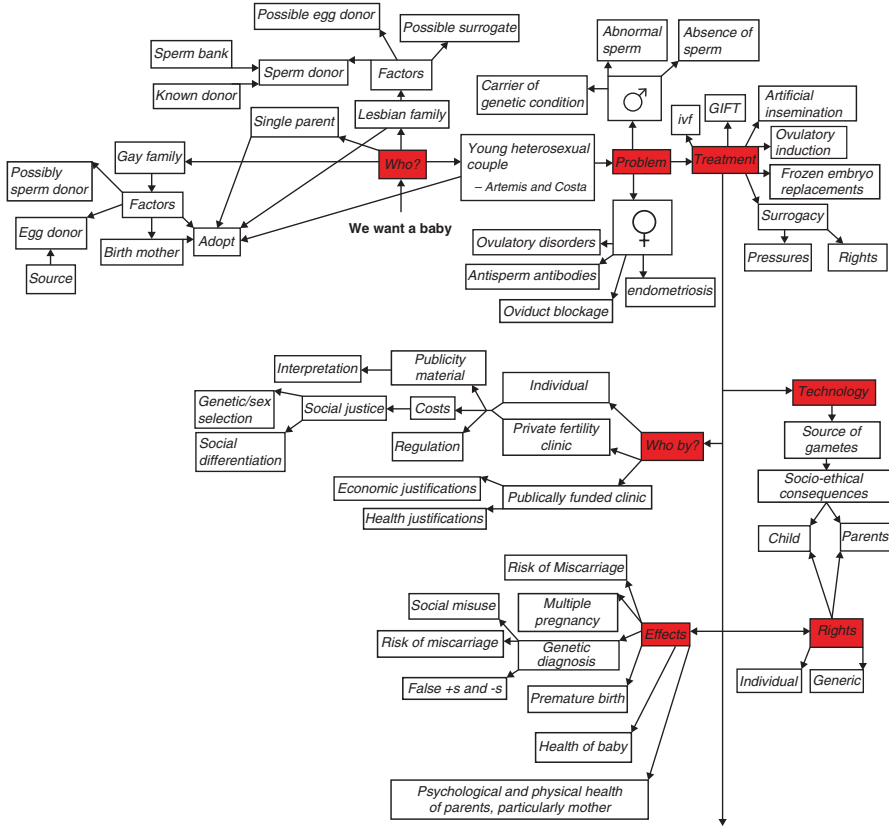


Fig. 22.3 Concept map – Assisted Reproduction

Hence, this raises questions at personal, social and global levels:

- What does this mean for me and my family? How do I feel about the possibility of AR?
- What do these questions mean for the society I live in?
- What are the global issues connected with this? What are the practices now and how do they promote diversity and inclusivity, compassionate justice and renewal of life?

Figure 22.3 represents the inter-connected issues that arise from the above questions about AR and link the social and political questions to the scientific context. An outcome of inquiry into this issue might be a leaflet produced by students which raises some of these questions, and suggested stimuli for discussion in science lessons.

Table 22.1 Constituents of SSIBL activities

Activity/Aspect	Interest for students	Outcome	Science knowledge
Animal house	Animal welfare and fuel costs	Model selected for a more fuel efficient animal house	Transfer of energy Homeostasis
Sugary drink dispenser	Health aspects of high-sugar drinks	Alternative means of raising money through healthier drinks; increased political participation	Diabetes; effects of sugar on body
Assisted Reproduction	Interest in new reproduction technologies	New teaching resource	Reproduction; ivf

22.3.3 *School Animal House*

Studying heat transfer, the teacher might use a number of examples, including the school animal house. Pupils in a school might be aware that the animal house is quite old, and can become over-warm in summer and too cold in winter. As a result, in winter, the heating system has to be kept on to keep the animals warm and, in summer, the fan has often to be kept running to cool the animals. This extra use of electricity impacts on the school's electricity bills and pupils can relate this to excessive and unnecessary use of fossil fuels at a global level. They could draw on their knowledge of heat transfer to solve the problem and, as a class, generate the question: 'What is the best design for the school animal house?' It has to maintain a steady temperature (knowledge of small warm-blooded mammals) under different weather conditions. The planning stage might involve different groups testing different materials and designing small-scale models to check their predictions. Each group designs their own model and tests how well they maintain a steady temperature in different ambient temperatures (high and low). Some time is allowed to change designs, if necessary, and then each group presents their findings to the year group. The best design is selected and the pupils build the animal house (or employ a company to build the house according to their plans). Tests are carried out once the animal house is built to check that it is working properly, and they also assess changes in fuel bills as a result of their design. The details of their inquiry are presented at the local teachers' science education meeting.

Table 22.1 outlines the age range, the scientific knowledge that needs to be recontextualised and applied for each inquiry activity and possible action points.

22.4 Explaining the Framework

SSIBL is comprised of an overarching context, RRI, and three interconnected pillars: CE, SSI, IBSE underpinned by an engaged pedagogy (Fig. 22.1). I discuss each of these, in turn, below.

22.4.1 RRI

Technological developments, inspired by research and innovation, both have an impact on, and are influenced by, social values and social change. Owen et al. (2009) identify three underpinning features of RRI:

- (i). Science *for* Society (SfS),
- (ii). Science *with* Society (SwS), and
- (iii). coupling of research and innovation with responsibility (R&R).

Science *for* society focuses on public values, i.e. normative motivations; science *with* society on dialogue and deliberation, i.e., substantive motivations; and, coupling of research and innovation with responsibility as a recognition of practices of science, uncertainties and risks associated with development of any technology and how these might be anticipated and managed (Ravetz, 2005).

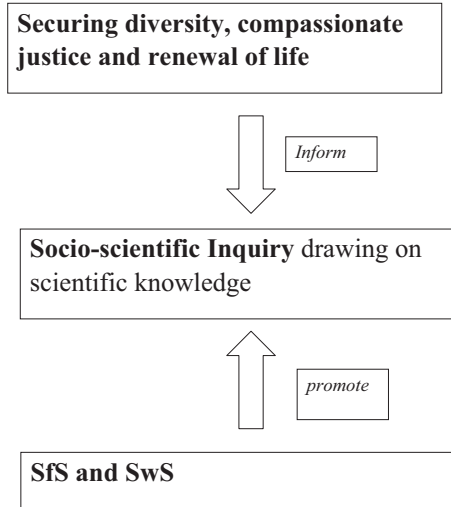
Science *with* society is participative. This acknowledges that those affected by the technology, as well as scientists, can influence decisions both at the upstream stage (that is, when the scientific ideas are initiated and possible consequences anticipated) as well as downstream at the point of production, application and distribution. Participation and dialogue in research assume knowledge and understanding of the underlying science, as well as critical appreciation of processes of the research both in its scientific and social components. Participative R&D is, therefore, a multi-agency approach to research and innovation because knowledge is differentiated and distributed in form (i.e., from academic knowledge, including different disciplines, professional knowledge, knowledge-for-living) (Layton et al., 1993). These foreshadow interactions between formal (curricular) and *informal* (non-curricular) knowledges.

In discussing values, people are identifying not only norms by which societies cohere but also those that are desirable. These can reflect a conflict between market-driven economies and needs for ethical relationships between people within a sustainable society. For example, drives for economic growth can potentially stimulate development of alternative technologies that support sustainability and zero carbon outputs. However, it can also endanger desirable outcomes because economic growth drives increasing levels of consumption; hence, the need for critical approaches that identify, problematise and raise questions about underpinning *values*. SfS is the process where science takes into consideration ‘the values, needs and expectations of society.’ (ec.europa.eu/programmes/horizon2020/sites/horizon2020/files/FactSheet_Science_with_and_for_Society.pdf).

Underpinning a curriculum and pedagogy that aims at enhancing human capacities within socio-cultural realities in which people live, Roger Simon (1992) derives three principles: *securing diversity*, *compassionate justice*, *renewal of life* (Fig. 22.4).

Securing diversity assumes differences between people (and non-human species) from classrooms to the whole planet entailing an ethic of respect. This implies opening participation in classrooms to young people who are often prevented from fully-engaging, and understanding that needs, interests and voices of people and communities across the world are mediated by power relations and have unequal status. Recognising diversity means inclusivity in terms of impacts science and technology have on a whole range of stakeholders, including those who cannot

Fig. 22.4 Relationships between RRI and socio-scientific inquiry



claim a stake for themselves but who are affected by impacts of the technology. It is an opportunity for disadvantaged groups to gain and use relevant knowledge.

Disadvantage and marginalization can be problematic to recognize and address, particularly where school systems are not adapted to such needs, and where there are deep-rooted social, cultural and economic factors. These can take different forms and kinds of solutions. Where there is purposeful liaison with a particular community; e.g., the Roma communities in different parts of Europe, and recognition of legitimate identities, there can be clear gains in ways in which students meet their legitimate aspirations (Nistor et al., 2014). Where schools can seem threatening and oppressive to some groups, arrangements can be made to carry out inquiries in other arenas outside of them (Ellsworth, 1989).

While recognising diversity implies openness (willingness to listen to others, respect what others have to say, and change one’s mind if convinced by better reasons), it does not imply agreement. What drives dialogue is difference and controversy (Hess, 2009).

Compassionate justice, minimisation of suffering, is a driving factor within RRI. Science *for* society, means that fruits of technology are distributed fairly, and that we have a mutual obligation to fellow inhabitants of the planet and a sensitivity to power relations which often distort those obligations. Renewal of life can be expressed as recognising “the interdependence of human life within a living planet as a source of both constraint and indeterminacy of human plans” (Simon, 1992, p. 27). Taking sustainability seriously entails respect for responsibilities we have towards each other.

22.4.2 *Citizenship Education (CE)*

CE can be seen as a continuum from knowing what is entailed by citizenship to having a more active concern for seeking justice. The term *critical* CE can also be interpreted in different ways from one which focuses on critical thinking to an

emphasis on praxis; i.e., reflection and action as well as constructive dissent (Levinson, 2010). A useful framework, in the light of activities discussed, to represent the dimensions of critical CE is adapted from Johnson and Morris (2010) (see Table 22.2).

The horizontal row: politics, social, self and praxis, represent the component elements of critical citizenship education while the vertical column represents the necessary attributes. Each cell describes how each attribute exemplifies each element with the brackets indicating how they might be manifested in the context of SSIBL within the classroom.

Deliberative dialogue is at the heart of the democratic process that incorporates the substantive meaning of dialogue as communication between participants but also the appropriate dispositions, such as listening, equality, respect and openness (Rice & Burbules, 1992) that presuppose constructive dialogue. In addition, this dialogue incorporates criticality, an ability to identify and respond to logical inconsistencies and unsupported assertions. Reasonable people hold their views open to criticism and are prepared to justify them or revise their views in the light of more compelling arguments. Deliberation goes beyond dialogue in that, in the democratic context, it involves free and equal citizens giving reasons to settle socially urgent questions (Simonneaux, 2014) on which they have divergent views (Enslin & White, 2003). In the context of schools, deliberative dialogue has much in common with Neil Mercer and Karen Littleton's (2007) construct of group exploratory talk, in which students share relevant information about a problem, listen actively, and where everyone contributes, helping to build up on ideas to reach agreement. This drive towards consensus is one of the historic features of democratic deliberation (Habermas, 1984). While these features need to be aspired to in the democratic classroom, this is not always the case because dialogue is always mediated by power, which can be through positions of status (teacher and student), differential access to knowledge (scientist and layperson) and inequalities in social and cultural capital (Gamarnikow & Green, 2000). Effectively, this means that what might be seen as a normative view by most students in a classroom might be seen very differently by one or two others who might feel disinclined to make their views known, again a case of inclusivity. For example, a teacher and the class might start off from the proposition that global warming is an important issue to address while a small few may feel differently, perhaps because they feel far more pressing concerns or that people close to them have very different views from the rest of the group.

Democratic deliberation needs to be fostered in the classroom and cannot be assumed. It also presupposes an environment where students trust each other as well as the teacher and where questioning habits have been encouraged. The SSIBL process itself can encourage such an environment but encouraging constructive dialogue in the classroom might need to be built up and nurtured over a period of time. How conditions for constructing democratic deliberation in the classroom are facilitated depends on the teaching and learning context. In an environment where teachers and students are used to arguing and discussing in an open and respectful manner, attain-

Table 22.2 Dimensions of critical citizenship education which incorporates principles of compassionate justice, securing diversity and renewal of life

	Politics (ideology)	Social (collective)	Self (subjectivity)	Praxis (engagement)
Knowledge	Knowledge and understanding of political systems and power structures. (understands where authority lies, e.g. that school student council, governing body and Principal, will need to be influenced to effect change)	Knowledge of interconnections between culture, power and transformations; knowledge of non-dominant as well as dominant discourses. (appreciates that there are a variety of opinions and to look out for marginal voices, e.g. 'silent' third world egg donors)	Sense of identity (understands how they are positioned in relation to a particular issue, e.g. right to buy fertility treatment)	Knowledge of how to collectively effect change for social justice. (knows how to garner support to effect change, e.g. campaigning against, sugary drink dispenser)
Skills	Critical political analysis. (Understands relationships between power, culture and knowledge; hence ideas of status of knowledge – the relationship between expert, anecdotal and communal knowledge)	Capacity to engage in dialogue and deliberation. (e.g. take part constructively in classroom discussions, both face to face and online)	Reflect on own status in society. (can place themselves in others' shoes while aware of their own position)	Imagining a better world; active participation in acting collectively to change status quo. (Articulates a vision of a better world and how to implement that aspiration practically)
Values	Commitment to values opposing injustice and oppression. (Advances an understanding of causes of injustice and how it relates to their own value system)	Inclusive dialogical relationship with others; ability to reflect others' values and commitments. (Can articulate viewpoints of others even where there is disagreement)	Consideration of self-worth. (Expresses why they have a particular perspective and its meaning to them)	Informed responsible, reflective ethical action. (Action taken is thoughtful and reflects underpinning values)

(continued)

Table 22.2 (continued)

	Politics (ideology)	Social (collective)	Self (subjectivity)	Praxis (engagement)
Dispositions	Actively questioning social injustice and oppression. (Raises critical questions about acts of injustice which can then generate questions for enquiry)	Responsible towards self and others. (keeps social responsibility foremost in thinking)	Autonomous and critical (Can listen to others' perspectives but maintains their own view, albeit self-critically)	Commitment and motivation to change society responsibly. (Communicates reasons for actions to others)

Adapted from Johnson and Morris (2010)

ing SSIBL will be relatively unproblematic. However, in more authoritarian learning environments many adjustments will need to be made, hence the structural and political positioning of schools within a broader social domain. A more gradual approach is necessary where students could be taught procedures for group talk then go on to develop their own procedures.

Critical citizenship education also incorporates a knowledge of political and moral concepts such as rights and equality. These are not necessarily mutually supportive concepts: ensuring equality might mean restricting rights. While rights — with responsibility — and equality are desirable, they can only be discussed in relation to their limitations. For example, if parents have the right to pay to choose the sex of their baby, this will have implications for equality, ethical values and natural justice. Interdisciplinary arrangements in school may be needed to foster these components, for example, planning for SSIBL with science, history and citizenship teachers collaborating.

22.4.3 *Socio-scientific Issues (SSI)*

Socio-scientific issues comprise conflicting opinions about a course, or courses, of action that have a scientific content and impact upon communities or society. They are controversial when good reasons can be given for conflicting opinions and/or courses of action (Dearden, 1981). There can be different levels of controversy. At one level, a controversy might be solved upon the production of relevant evidence, e.g. differences about the best material for lagging an animal house can be tested based on experiments to measure temperature difference. On the other hand, there may be core differences of values which are less easily settled, such as whether it is

right or wrong to abort a foetus under certain conditions (Levinson, 2006). Where there is controversy, particularly as they impinge on core values, strong *emotions* may be aroused. It is important that such matters are dealt with sensitively, that participants are listened to with critical respect, and encouraged to be open and honest (Hodson, 2014). This is not an easy situation to achieve and will depend on the culture and the nature of collaboration within the group. One of the skills underpinning teaching SSIs and also SSIBL is to help create an atmosphere of mutual respect in the classroom, attempting to understand what is in the mind of the ‘other’.

Learner competencies in SSIs include employing ‘scientific ideas and processes, understandings about science and social knowledge (e.g. ideas about economic and ethical influences) to issues and problems that affect their lives’ (Sadler, 2009, p. 13). Goals for student participation in SSIs vary. Some see the main goal as being legitimate participants in social dialogues that are science-related (Sadler, 2009) while others maintain that *socio-political action* is a more urgent outcome (Bencze & Alsop, 2014). Socio-political action implies asking questions about ‘how research priorities in science are determined’ (Hodson, 2014, p. 68), whose interests are considered in formulating policy, and how action can influence policy decisions. It also implies commitment to reflective change, while Wolff-Michael Roth and Angela Calabrese Barton (2004) propose that such action is necessarily collective (see Table 22.1). In SSIBL, we encompass goals emphasizing participation and socio-political action, indeed the second presupposes the former. While RRI presupposes participative dialogue, inquiry into SSIs is *non-trivial*, i.e. it involves students as critical citizens who learn how to enact goals which reflect aspects of social justice. (By non-trivial we draw a distinction between activities which involve simulation, i.e. writing a letter to a political leader as an exercise where the letter will never be sent, as compared with actions which are enacted, and *realised*, through the process of social and political participation. However, an action might involve deciding not to change if, for example, such a change risks too much harm.)

SSIs, and hence SSIBL, present particular challenges for organising learning and assessment, precisely because they are transdisciplinary and context-dependent. Approaching an issue depends to a large extent on our personal history, our social situation, our intentions, needs and wants, and our knowledge and experience of the issue. Stein-Dankert Kolstø (2001) offers a framework for examining the science dimensions of SSIs which have potential for contributing towards an assessment framework. These are:

- (i). Science-in-the-making and the role of consensus — how is scientific knowledge made and how do its claims come to be validated?
- (ii). Science as one of several social domains that contribute towards decision-making. This is central to SSIBL because there are a number of issues which are ostensibly based on science but where science knowledge may not be the main factor in decision-making, see for example Chris Dawson (2000). In these formal school science might be redundant (Ryder, 2001) and expert knowledge might itself be contested (Layton et al., 1993).

- (iii). Distinguishing between descriptive and normative statements.
- (iv). Demands for underpinning evidence. In some cases evidence may be unambiguous but in complex SSIs this is rarely the case. It also involves matters of trust about whose evidence is more convincing, and how that evidence was amassed.
- (v). Scientific models as context-bound which raises questions as to how scientific models are applied to complex situations involving a range of social and political factors.
- (vi). Values; the way in which values influence our thinking and responses to an SSI.
- (vii). The relationship between scientific evidence, i.e. that which comes from experts and anecdotal evidence, which comes from a range of lay sources.
- (viii). Suspension of belief, being sceptical about the relationship between evidence and the conclusions which can be drawn.
- (ix). A critical attitude, learning to ask the questions which are able to scrutinise knowledge claims.

All these dimensions have relevance in SSIBLs and values and critical attitudes apply to transdisciplinary inquiries generally. While these dimensions are unlikely to feature simultaneously in SSIBL they are, nonetheless, helpful as pedagogical resources to support decision-making and argumentation.

Rosemary Hipkins et al. (2014) use the term ‘wicked problems,’ which illustrate well the kinds of controversies to which SSIBL aspires. These are serious social challenges that span multiple domains (social, economic, moral, aesthetic, political) and link closely with other problems. There are no clear solutions and different groups of people believe they have answers which often contradict one another. ‘Wicked problems’ do not have finite or unambiguous answers but in dealing with them, other interesting questions emerge.

22.4.4 Inquiry Based Science Education (IBSE)

At the core of the SSIBL framework is inquiry-based learning. Inquiry in the U.S. was promulgated by the philosopher and educationalist, John Dewey (1916). Dewey saw its democratic potential as a means for citizens to participate through solving problems of mutual concern and developing habits of mind of curiosity and communality. IBSE has been influential in science education policy, both through the National Research Council (2000) and the EU (Rocard, 2007) who conceive of science practice as question-driven and open-ended. The fundamental features of inquiry based learning are consistent with the proposed SSIBL framework: purposeful research-driven learning through collaboration, critical examination of evidence and experience. The main distinguishing point of SSIBL is that it involves an authentic open-ended question or hypothesis formulated by students, teachers or other interested parties, and taking action. Since student interest, research,

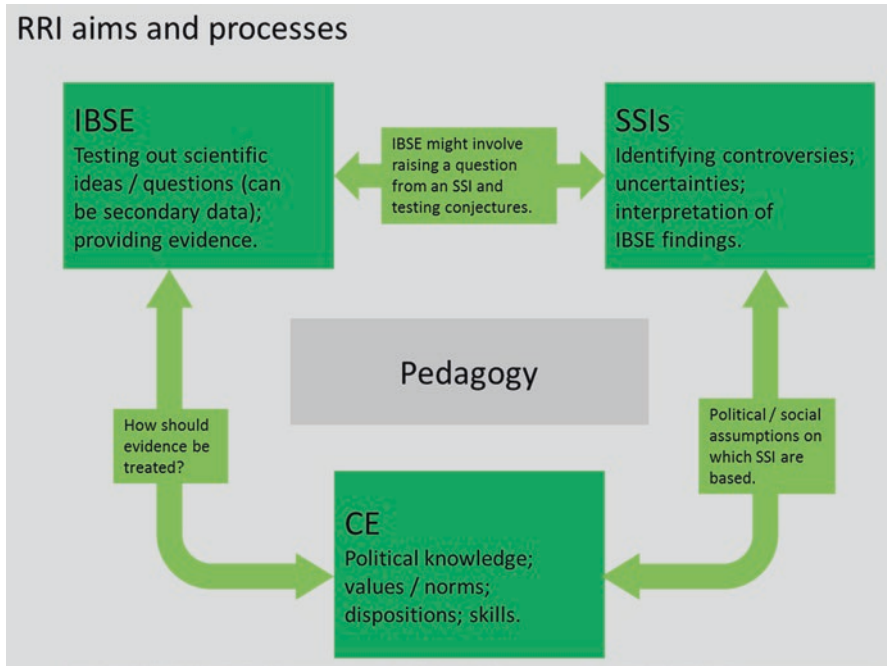


Fig. 22.5 SSIBL framework. Interconnections of the main pillars in SSIBL with RRI as the overarching context

questioning and the collection and interpretation of evidence underpin inquiry, they are components of the role of inquiry-based science learning in the SSIBL framework (Fig. 22.5). However, there are no specific design stages to inquiry-based learning in SSIBL. Student interest is not always spontaneous and, in most cases, will involve teacher preparation and competence in nurturing student interest. Inquiry in the context of SSIBL has features that are quite distinct from those normally attributed to inquiry based learning in science education.

22.4.5 *Scaffolding Inquiry Teaching and Learning*

Since our characterisation of inquiry is seeking knowledge through evidence to answer authentic questions, inquiries need to be based on student interests. Through the introduction of inquiry-based learning, students should feel empowered to direct their own learning through collaboration within a community of learners. Students might find it difficult to generate researchable questions if inquiry-based learning is new to them. One strategy for reaching the stage of genuinely open inquiry is first through a structured approach, then through guidance with teacher support and then open inquiry, similar to a STEPWISE apprenticeship approach, although teacher

judgment here is crucial. Too great a dependence on structured inquiry could impede moves to open inquiry.

Scaffolding is the process whereby learners are given appropriate support to help them learn something which they could not achieve on their own. It is a central pivot to social constructivist learning because it presupposes support can be given at a stage when the student is ready for it and can then be phased out when the learner has acquired the required competence. The precise nature of the support depends on a range of factors, what needs to be learned, the knowledge and skills the learner already has, the experience they have of the context of learning, the complexity of the concepts and skills to be learned, the knowledge and skills of the facilitator.

Time is also a factor. Short term inquiries would have outcomes that could be completed in one or two lessons or sessions and carried out mainly within school. Long term SSIBLs would go beyond this time and often include external agencies. Examples of short term SSIBLs are;

- Situating a feeder for nesting birds;
- Designing a poster to reduce school energy consumption;
- Organising a system for building the school compost heap;
- Bringing in plants for a community garden;
- Producing a leaflet to show how to estimate maximum salt intakes.

Such short term projects can meet the framework for SSIBLs. As well as different time spans for SSIBL these can also be structured from inquiries which are mainly closed and directed mainly by the teacher to those which are more open. Structured inquiries will help make explicit to students the knowledge and procedures necessary to carry out an inquiry.

22.4.6 *Authenticity*

Questions generated through inquiry are deemed to be 'authentic'. However, 'authentic' risks being a catch-all term with multiple, sometimes contradictory, meanings. In the context of SSIBL, authentic questions can be the kinds of questions that scientists raise, although the discourse between scientists in a research project, often influenced by political, cultural and economic factors, will be very different from that of school science (Quigley, 2014). In NRC terms, authentic practice is linked to student ownership of the learning process, although that raises difficulties when students encounter learning experiences that are genuinely challenging and need guidance. The Galileo Educational Network (Galileo.org) conceives of authenticity as focusing on problems and issues relevant to students in the 'real world'.

For Anne Hume and Richard Coll (2010), authentic problems are those that are ill-defined, have no obvious solution, where data has not been collected and there are no established goals and methods, a condition which is unlikely to be attained in the vast majority of school-based inquiries in science. Rather than attempt an

overarching definition for authentic practice in SSIBL, it would be more helpful to identify its main components:

- (i). Proceeds from questions that interest and engage students and through which they express a wish, and choose, to find answers;
- (ii). A mutually-agreed purpose of all participants (i.e. a social authenticity);
- (iii). What is relevant and has value and meaning (i.e. personal authenticity); and,
- (iv). Where scientific ideas are a resource and can be activated to help find a solution to the problem.

There are, therefore, implications. A mutually-agreed purpose may go beyond the bounds of the school walls for participants, particularly where in finding the answers to questions, students might work with scientists, or other people with expertise. SSIBL might involve interaction either in informal education contexts and/or working with agencies outside the school. An example of this is a collaboration between scientists and students in a school in London with a high proportion of students of Bangladeshi origin. The collaboration stems from an inquiry into the pattern of diabetes in the family histories of the Bangladeshi community in east London. Students at the school, using their background socio-cultural knowledge, work with university scientists, health practitioners and the local political authority in devising a questionnaire. In the university laboratories under the guidance of scientists, students learn sophisticated analytical techniques on DNA found in affected families.

To ascertain what is relevant and has meaning is made real through participation and democratic dialogue where participants become agents of change transforming a reality that can be improved. Finally, activating scientific ideas as a resource might not be straightforward. It might involve distributed knowledge where different parties can contribute through their own experiences and expertise (Roth & Lee, 2002). But it also encompasses questions of scientific uncertainty. Consider, for example, a project that involves testing the pH of potentially polluted waters in a stream. Most school students when they encounter pH measurements use a pH meter or pH papers in ideal conditions. However, measuring the pH of a stream means taking flow, turbidity and temperature into account, thinking about sampling techniques, and being able to assess error. When students begin to work in non-ideal situations the limitations and uncertainties of scientific practice become clearer.

22.5 Developing the Framework for SSIBL

Based on the account above in elaborating the principal features of SSIBL, Fig. 22.5 models the possibilities for SSIBL incorporating the components from Fig. 22.1 and listed in the previous sections.

There is no set format for the order in which the pillars of an inquiry might be arranged. Inquiries might start with a question, followed by planning, perhaps reframing the question after planning, data collection and interpretation, and subse-

quently communication and taking action based on findings. These stages are likely to be iterated at various points, however. Alternatively, students might be exploring data, and research questions might emerge from the data. Data might involve carrying out surveys or using ethnographic methods.

Figure 22.5 is *a framework to be aspired to*. It is recognized that teachers will go through different routes in building up to SSIBL.

A ubiquitous question, particularly from younger students, is ‘What are we doing this for?’ For some activities, such as early-stage reading, the answer is long-term, complex and a straightforward answer might demean the purpose. But in the case of SSIBL, it is quite a legitimate question, and the socio-scientific purpose needs to be clear if the process is to have meaning.

Actions are linked to authentic practices, the aim is to change affairs from being unsatisfactory to more desirable ones. For example, there is a difference between students discussing the most efficient ways to conserve fuel use, or answering a set question on this topic, and those who design and build the school animal house based on an inquiry into the best way to cut down electricity bills. This action component is, arguably, a distinctive feature of SSIBL, and models that of STEPWISE. Hence authentic action components are oriented in the students’ educational and social settings, and they play a role in transforming the materiality of students’ lives, in however small a way.

Ideas or questions or hypotheses for SSIBL should aspire towards the following attributes:

- (i). Openness (i.e. no pre-set answer)
- (ii). Authenticity
- (iii). Comprise different and conflicting perspectives (i.e. controversy)
- (iv). Links between personal and social relevance.
- (v). Participatory (i.e. all students should be able to take part and co-operate in addressing the question)
- (vi). It should be researchable (i.e. either primary or secondary data can be gathered and interpreted to answer the question)
- (vii). Focus (i.e. it should be narrow enough so the relevant data is containable)
- (viii). Feasibility (i.e. it should be possible within time and curriculum constraints to answer the question)
- (ix). Epistemologically appropriate (i.e. it should draw on science knowledge which students have or can be taught, and/or support the building of relevant knowledge).

When studying a topic, students can have a space in which to formulate their own questions. There are a variety of ways in which this can be opened up. Students could brainstorm where they suggest various ‘raw’ questions, there is a follow up time to choose questions which students prioritise, followed by group work in which they frame the questions with the properties above (Table 22.3).

Table 22.3 Examples of SSIBL questions

Question	Level	Scientific knowledge	Other knowledge	Personal to social
Sun-tanning parlours should be banned for young people under the age of 18	Upper secondary	Radiation	Risk and uncertainty;	Relevant for young people in colder climates but raises broader questions about freedom of choice, global warming and damage to the ozone layer.
		Structure of the skin	Human Rights	
Selection against certain disabling genetic conditions is the thin edge of the wedge for wholesale genetic selection.	Upper secondary	Genetics;	Social justice;	Personal questions about attitudes to disability but broader questions about access to fertility treatment.
		Ivf techniques	Rights; Culture	
Is it possible to avoid resistance to antibiotics?	Upper secondary	Bacteria	Risk;	How do different legislation scenarios across the world influence individual decision-making about the rational use of antibiotics?
		Antibiotics	Legislation;	
		Infectious diseases	Personal and social decision-making	
		Evolution		
Does recycling paper do more harm than good?	Lower secondary	Manufacture of paper;	Process of paper production and recycling;	Personal attitudes to waste as against economic interests of those who pulp wood and produce paper.
			Cost-benefit analysis;	
		Chemical structure of paper;	Local recycling legislation;	
What's the best way to feed small birds?	Primary	Solvent chemistry	Interest groups	Local aesthetic pleasures of birdlife in the context of broader species competition and interaction.
		Bird nutrition;	Conservation	
		Food webs;		
How can we reduce car pollution outside our school?	Primary and Lower	Sampling; techniques		Local concerns about pollution related to global use of fossil fuels and alternatives
	Secondary	Fuel combustion;	Use of secondary data;	
		Sampling;	Pros and cons of car use	
		Measuring particulates		

22.6 Assessment

Assessment of students in SSIBL depends on the purpose of the assessment and the nature of the assessment — whether it is diagnostic, formative or summative.

Laurence Simonneaux (2014) identifies four didactic strategies, slightly adapted, that can also reflect assessment purposes. These are:

- A doctrinal strategy that aims at the acceptance of authoritative scientific concepts.
- A problematising strategy that focuses on students' reasoning through SSIBL.
- A critical strategy that aims to develop capabilities in scrutinizing claims, to be questioning of expertise and to appreciate the uncertain nature of science and its applications and that the development and production of technology carries risks.
- A pragmatic strategy to engage students and to promote student action.

The framework of SSIBL assessment is adapted from Table 22.2 and incorporates:

- Knowledge about an issue (both scientific and transdisciplinary).
- Skills in organizing and operationalising a socio-scientific based inquiry.
- Values that reflect issues of social justice and wellbeing.
- Dispositions that include recognition of inclusivity and democratic deliberation.

Table 22.4 is a grid that can be adapted depending on the context of SSIBL (Fig. 22.6).

22.7 Considerations in Relation to STEPWISE

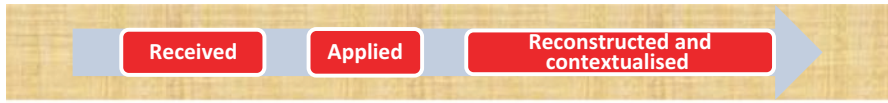
In conclusion, I want to emphasise three distinctive aspects of SSIBL.

1. Inquiry in SSIBL is not formulaic and might be quite different from inductive-based inquiry. It involves asking authentic questions where the solutions are diverse, politically-constituted and complex, and involves drawing on domains of knowledge beyond science. In that sense, they have much in common with the Socially Acute Questions approach (Simonneaux, 2014).
2. Inquiries should stem from students' own interests and motivations. This might not always be possible and is an aspiration. An important aspect of skilful pedagogy in SSIBL is helping to stimulate questions that promote a genuine sense of inquiry in students.
3. Actions of SSIBL are *non-trivial*. They involve informed actions which make a difference to individual and social wellbeing.
4. Actions are collaborative and enmeshed within a web of interested human and non-human relationships. Their realisation is therefore uncertain and the processes of achievement of aspirations based on social justice are risky. That leads to the production of knowledge-in-action, reflecting and acting on the inter-relationships between knowing the world and the vagaries of action, rather like disturbing a network of human and non-human actants (Hoeg & Benze, 2014).

Table 22.4 Example of assessment framework using school animal house project as exemplar

Didactic approach	Knowledge	Skills	Values	Dispositions
Authoritative (mainly structured)	Focus on learning substantive theoretical scientific knowledge and inquiry skills. (learn principles of heat transfer and experiments to measure them)	Follow through procedures as taught and relate findings to science knowledge. Explicate learned procedures. (Investigates conductivity of different materials using given experimental procedures and makes conclusions based on evidence.)	Learning that the applications of science are not value-free. (Principles of heat transfer can be applied and associated with improvement of wellbeing at personal and social level).	Discusses problem in groups.
Problematising (mainly guided)	Applying scientific and transdisciplinary knowledge into new contexts (explain how principles of heat transfer apply to the construction of an animal house, and reflect on human responsibilities to non-human species)	Devises procedures as taught for carrying out inquiry. This can be done with some guidance, if appropriate. Demonstrates awareness of uncertainty in considering empirical and second hand data. (Devises a method for investigating appropriate materials to build animal house. Takes into account concepts of accuracy, validity, precision and so forth in making and interpreting data).	Articulating that an inquiry is based on a range of value judgments. (Can articulate values associated with inquiry such as importance of fuel conservation, its local and global implications, and non-human wellbeing).	Recognises when to collaborate in groups and when to be autonomous. Participates fully.
Critical and pragmatic (mainly open)	Recontextualising and scrutinizing relevant scientific knowledge and research in the light of contingencies of specific contexts. (Recontextualise and adapt knowledge of heat transfer in the light of constraints of constructing an animal house, e.g. use of composite materials, ventilation factors, humidity. Research on habits of small mammals to reflect design constraints. Reflect on ethical relations between humans and non-humans in terms of concepts such as rights and responsibilities, and process of fuel conservation).	Suggests and collaborates as group to generate questions or hypotheses for building animal house using research material, scientific and other knowledge, reports and surveys. Follows through inquiry. Adapts knowledge and understanding depending on circumstances. (Develops inquiry and outcome, eg working model of animal house, and evaluates process and product).	Inquiry driven by value considerations recognizing various aspects such as inter-relationships between personal and social values. Recognises interconnectedness. Identifies political nature of action where necessary. (Construction of animal house driven by awareness of need and knows how to take action to meet that need.)	Can operate between full autonomy and collaboration. Recognises importance of inclusivity and how to negotiate consensus.

Knowledge



Skills



Values



Dispositions



Fig. 22.6 Summarises assessment for progression through the four dimensions of knowledge, skills, values and dispositions

The last point does raise the question of what is meant by action. Just as the social applications of technoscience carry accompanying hazards, risk and uncertainties (Ravetz, 2005), so the intentions of actions are carried out in a sea of uncertainties. An example is an incident based on the AR activity described above where a discussion among students resulted in homophobic sentiments being expressed, which were then challenged. For any action in the social world to succeed, it must rely on collaboration and an element of reliance on others (Arendt, 1998). Participation and trust are crucial in a diverse and plural society where values might vary enormously. So, the achievement of a particular outcome is only a partial measure of success; the importance of negotiation and participation based on shared knowledge, and the understanding of what is possible in sometimes unpromising circumstances, is a core part of the learning process.

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