Introducing socio-scientific inquiry-based learning (SSIBL)

Ralph Levinson

Abstract The case for socio-scientific inquiry-based learning (SSIBL) based on the EU PARRISE project in schools is presented through three pillars – citizenship education, socio-scientific issues and inquiry-based science education (IBSE) – within the overarching context of the EU Responsible Research and Innovation (RRI) initiative. Integrating these pillars provides a model for using and building scientific knowledge to enable change by asking authentic questions ('Ask'); doing an inquiry ('Find out') and taking action ('Act').

Science and technology influence our lives at local and global levels, on an everyday basis and in the long term. Renewable fuels, personalised medicines and communications systems all have the potential to transform our lives for the better. But there are scientific uncertainties in their development and social risks in their impacts. Renewables, for example, are viable solutions to replace fossil fuels. But there are costs and job losses associated with their introduction, and environmental hazards implicated in producing materials such as those in solar cells.

Because there are both social and scientific costs and gains in the development and use of many contemporary products, they generate controversy. Addressing these issues through an inquiry approach is core to socio-scientific inquiry-based learning (SSIBL). SSIBL attempts to find answers to those socio-scientific questions we face, and, within a STEM (science, technology, engineering and mathematics) programme, raises challenges that young people might want to do something about. SSIBL has been developed as part of the European Union (EU) PARRISE programme (Promoting Attainment of Responsible Research and Innovation in Science Education; for further information, see www.parrise.eu).

Science teachers are often concerned that exploring ethical and social questions detracts from the core scientific knowledge and understanding that is needed for passing science examinations. This is why scientific content is crucial to SSIBL. But we argue that engaging with the personal and social aspects of these questions deepens knowledge and also problematises it. It makes us more critical, practical and understanding. Box 1 provides a summary of the main features of SSIBL.

Box 1 Main features of socio-scientific inquiry-based learning (SSIBL)

SSIBL for teachers:

- is a practical tool for enhancing teacher practice;
- builds effectively on everyday teacher practice;
- draws on state-of-the-art knowledge in science education;
- fosters opportunities for implementing curriculum requirements;
- *links to real-world developments in science and technology;
- *provides a means of collaborating with agencies beyond the school curriculum;
- *encourages young people to ask questions that interest them and to enact change in the real world.

Those marked * apply, of course, to students too.

Inquiry is core to SSIBL. Inquiry means to ask questions and seek insights into problems that intrigue us. These questions can be broad but also focused. They can arise from curiosity about natural phenomena, or be more socially oriented. What's inside bubbles? Do birds sleep? Is chocolate bad for you? Is cycling to school really healthier than going by car? Are new technologies all that they claim to be? SSIBL is therefore different from regular forms of scientific inquiry in schools because it is based on scientific methods *and* social considerations

This article is a shortened version of Levinson, R., Knippels, M.C., van Dam, F., Kyza, E., Christodoulou, A., Chang-Rundgren, S.N., *et al*. (2017) *Science and Society in Education. Socio-Scientific Inquiry-Based Learning: Connecting Formal and Informal Science Education with Society*. Available at: www.parrise.eu/wp-content/uploads/2018/03/parrise-en-rgb.pdf.

The SSIBL model

Within the overarching context of the EU Responsible Research and Innovation (RRI) initiative (www.rri-tools.eu/about-rri), there are three interacting pillars to the SSIBL model:

- citizenship education;
- socio-scientific issues (SSIs);
- inquiry-based science education (IBSE).

Responsible Research and Innovation (RRI)

RRI is a crucial element of the EU's recent science and technology policies. The aims of RRI reflect the importance of public and stakeholder participation and mutual responsiveness – working *with* and *for* people – to product development in science and technology. In other words, how can science and industry develop knowledge and technology that is *socially desirable, ethically acceptable* and *sustainable*? For example, are genetic testing kits that can be bought via the internet socially desirable? How can we challenge the exploitation of resources in producer countries for the benefit of wealthy countries – what is ethically acceptable? And how do we ensure that new processes and products are sustainable from an environmental and political/social point of view?

Citizenship education

SSIBL supports young people in acting as knowledgeable social agents through citizenship education (Box 2). It involves young people making decisions together, which they then can enact. In a democratic society all stakeholders should be able to contribute and therefore SSIBL activities should encourage participation and dialogue (science *with* people) throughout the activity, from raising questions, through carrying out an inquiry, proposing solutions and taking action (science *for* people).

Socio-scientific issues (SSIs)

SSIs provide the scenarios for raising inquiry-based questions. SSIs use scientific knowledge to address a social issue. For example, young people need to understand the relationship between fuels and energy to appreciate that conservation of fuels is paramount in economic and social terms. A biological understanding of the importance of oxygen diffusion to the cells that prompts concern about the personal and social harms of smoking, and what might be done about it, exemplifies the relationship between science and social issues.

Box 2 Features of citizenship education in SSIBL

The core idea of citizenship education in SSIBL is to participate critically in taking action.

- Argue a point with personal commitment using evidence and reason.
- Listen carefully and considerately to what others have to say.
- Be open to changing your views. If another participant advances a better argument, judge it on its merits.
- Respect the views of others. All participants have a right to put their views forward and be listened to. Racist, sexist and homophobic statements, and any statement demeaning the identity and character of a participant, are neither respectful nor inclusive and have no place in constructive dialogue.
- Be critical of arguments if there are points you disagree with, if they are based on insufficient evidence or on shaky premises.
- Encourage passion and commitment. Participants who have a very passionate and deep commitment to a particular viewpoint can sometimes stifle dialogue. But under conditions of openness and transparency, this can often be put to good effect because it helps other participants to reflect more fully on their own views (Levinson, Hand and Amos, 2012).

Sometimes SSIs can be in the form of a dilemma or controversy, but this need not always be the case. For example, school students might agree that they want to keep their classroom as warm as possible in winter but differ about ways to go about it. Controversies take place when different parties have opposing arguments but where the arguments are bolstered by good reasons. People might agree that climate change is an urgent issue but disagree about the best way to tackle the problem.

In SSIBL, SSIs involve:

- **Aspects of disagreement or controversy**.
- **Reasoning**. Discussion of SSIs is likely to involve both informal and formal reasoning. When students talk about their perspectives on an issue from their everyday experiences, they are often using informal reasoning. Drawing on scientific knowledge through consistent logic to justify an opinion is an example of formal reasoning. Both types of reasoning are valid depending on the context, and students should be encouraged to distinguish between the two forms of reasoning. Sadler, Klosterman and Topcu (2011) show that engaging in SSIs can support learning of science content, although the learning is sharper if students are interested in the issue, that is, if it is authentic.
- **Uncertainty and risk**. Many SSIs involve an appreciation of uncertainty and risk. Students

should be encouraged to distinguish between different types of uncertainty. Taking measurements with a thermometer involves a degree of uncertainty depending on the precision of the measuring instrument. Predicting social impacts, such as whether young people will give up smoking even when knowing the biological hazards, is an example of social uncertainty. Risk is related to the chances of a hazard occurring. Older students should be able to distinguish between relative and absolute risk, and also understand that factors other than probability affect estimation of risk (Levinson, 2011).

Sometimes, students come along with issues or questions that they are keen to address. But it is more likely that the teacher will help to stimulate interest in a particular theme using pictures, video clips, cuttings from newspaper reports and social media, which connect to students' lives and concerns. For example, Amos and Christodoulou (2018) in this special issue of *School Science Review*) illustrate the damaging impacts of producing smartphones using video clips of mining coltan.

Inquiry-based science education (IBSE)

Students need skills and knowledge to provide the necessary evidence to find solutions to an authentic question (see Box 3). These skills involve collaboration with others and finding out the viewpoints of stakeholders, as well as doing experiments.

Doing experiments might involve coming up with ideas and testing them, collecting and evaluating data, an awareness of uncertainty in the data collected and its interpretation, and possibly asking new questions as a result of reflecting on the data. Having collected evidence, students need to explain how the evidence helps them to answer their questions. But they might need to explore other ways than doing experiments for collecting data. They might, for example, find out stakeholder views before taking any action, and this might be done through a social survey.

Scaffolding student learning is important, particularly when students are new to inquiry learning (Box 4).

Box 3 Approaching SSIBL through IBSE

Once students have explored a scenario for an issue, they need a good *research* question for their inquiry. Finding a good research question is not an easy task and will need support from the teacher. The question has to be *researchable* and have the following characteristics:

- the question fits the theme or scenario;
- the question is open, and the answer not known;
- there is only one question (e.g. what are the main reasons year 9 students in our school give for smoking?) (note that groups of students in an inquiry can pursue different research questions, as long as each group is only following one question);
- the question is clear and focused;
- the question is feasible – it is answerable and can be addressed in a fixed time;
- data can be collected to answer the question.

Box 4 Scaffolding

There are a variety of ways in which teachers can scaffold learning through inquiry. For example:

- stimulating thinking about authentic questions;
- providing sensitive prompts;
- helping students to distinguish between different procedures (e.g. the kind of data that supports a prediction);
- helping students to make distinctions between models (e.g. measuring the heartbeat of *Daphnia* under various conditions) and human systems;
- mapping out procedures using drawings or web-based tools;
- role-modelling a reasoning process;
- providing knowledge when needed.

At first the teachers could set a particular question for students to explore. For example, teachers could ask students to find out the sites of the school's greatest energy losses in winter so that they could make a case for action for better insulation. Some of the possible approaches are given in Box 5 where the teacher could have a prepared set of prompts for the students.

One of the distinctive features of IBSE *within* SSIBL is that the inquiries are open and not predetermined

Box 5 Example of a scaffolded inquiry

Question	How can we cut down the school's energy losses in winter?
How to organise	How do we ensure everyone has a say? What do my friends think we should do? How do we decide on the best way of going about this?
Things to think about	Where are the best areas in the school to investigate? When should we take measurements? What equipment should we use? Should we take measurements at different times of the day?
Collecting data	How will we record the data? How can we make sure our data are accurate?
Interpretation	What do the data tell us? Where are the greatest energy losses taking place? What can we do about it?

and can involve a range of approaches, including experiments, surveys and debates.

SSIBL should not be time-consuming. Particularly when starting out, short-term SSIBL can be very effective. Examples of short-term SSIBL activities are:

- designing a poster to reduce school energy consumption drawing on knowledge of heat transfer;
- 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.

As well as being carried out over various time spans, SSIBL can be structured through inquiries that are mainly closed and directed mainly by the teacher as well as through those that are more open. Structured inquiries will be an important stage to help make explicit to students the knowledge and procedures necessary to carry out an inquiry.

SSIBL in practice

By combining the three pillars of SSIBL, we have generated a model (see Figure 1 and Box 6) that consists of three stages: 'Ask', 'Find out' and 'Act' (see also www.parrise.eu/our-approach/).

Note that this model does not necessarily have to be followed sequentially. A question might arise from

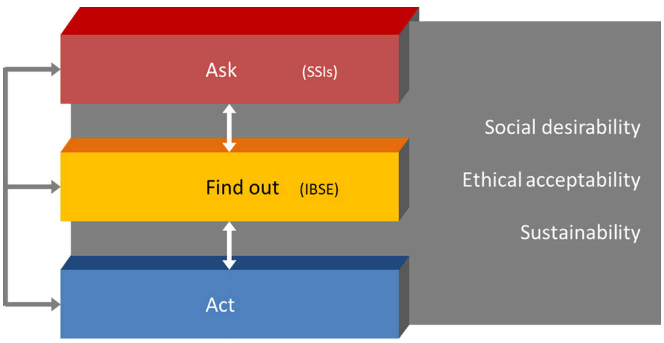

Figure 1 The SSIBL model

Box 6 Summarising SSIBL

SSIBL features three main stages:

• Raising **authentic questions** about controversial issues (**SSIs**) arising from impacts of science and technology in society.	['Ask']
• **Enaction**: Integrating social and scientific inquiry (**IBSE**) to explore these open-ended questions.	['Find out']
• **Action**: Formulating solutions that help to enact change.	['Act']

an investigation; for example, students investigating nutritional qualities of foods might be prompted to link this to a news item on imported fish (see Romero-Ariza, Abril and Quesada (2018) in this special issue of *School Science Review*).

SSIBL in the classroom: cutting down the school's energy losses

A class of key stage 3 students (ages 11–14) is studying energy. They come to understand that energy is the ability to do work and make changes take place. They learn that energy can be recognised through processes involving light, motion, heat, electricity and sound. They also know that their bodies use energy to make things happen, such as lifting weights, walking to school and keeping warm at low temperatures. Intuitively, they grasp the idea that they need food to do these things, but they are not quite sure how food plays a role in this. So they are taught that food can be seen as a fuel like petrol, coal, or gas – stuff that makes vehicles go and keeps us warm at home. Through observations and experiments, they see that nothing happens to fuels unless there are certain conditions: the presence of oxygen and a source of heat.

Through discussions about their experiments and the relationships of energy use to their own lives and to the planet more generally they come to understand that fuels need to be conserved. So they decide to investigate how their school manages its energy use so that it remains warm during winter and cool in summer. Their inquiry takes place in four stages:

- They develop a plan for resolving the question of fuel conservation in the school. Their overall question becomes *How can we avoid energy losses in the school?* ['Ask']
- They carry out a survey identifying sites that are cold and draughty in winter or hot and uncomfortable in summer. ['Find out']
- They search for information, and try out small experiments (such as how temperature loss can be reduced from a cup of hot water using different types of material to cover the cup) for reducing energy flow in winter and increasing it in summer. ['Find out']
- They design a pamphlet to suggest ways of making the school more energy efficient based on their evidence, including reducing use of lights and computer equipment, and they discuss it with school management at the school 'energy day'. ['Act']

This activity involves teaching about fuels and energy transfer, for example that:

- energy is transferred usefully, or dissipated;

Box 7 Summary of the SSIBL process through investigation of classroom heat loss

Topic	Cutting down a school's energy losses
Science content	Energy transfer, fuels, fuel conservation, insulation, thermal imaging, data gathering, sampling.
'Ask'	Where does the greatest heat loss take place in school? What can we do about it?
'Find out'	Best ways to measure heat loss; gathering accurate data; interpreting the data; efficacy of insulators; research into energy conservation in buildings.
'Act'	Presenting information to the school authorities and school council about heat loss and ways of ameliorating the problem. Devising the message in the most appropriate ways to convince decision-makers.
Social desirability	Identifying means to improve the comfort and wellbeing of school students through effective costing.
Ethical acceptability	Consequences of actions are to improve conditions of learning, maximising benefits to all parties.
Sustainability	Fuel conservation.

- fuels are needed as a starting point in an energy transfer system;
- fossil fuels need air and a source of heat;
- heat flows from regions of high to regions of low temperatures;
- energy transfer can be managed, thereby conserving fuels and cutting down costs.

Box 7 summarises the SSIBL process.

Concluding comments

SSIBL is a means of both integrating and building scientific knowledge through investigating questions stimulated by the interests of young people. It is being adopted throughout Europe through the PARRISE project, which focuses on teacher development in line with greater public participation in the development of science and technology for the betterment of humanity. We recognise that SSIBL activities need to be incorporated into the curriculum. As the articles in this special issue of *School Science Review* will demonstrate, there are many ways this can be done to enhance students' understanding of scientific principles.

Acknowledgement

This work has received funding from the European Union's Seventh Framework Programme for research, technological development and demonstration under grant agreement no 612438, PARRISE project: Promoting Attainment of Responsible Research and Innovation in Science Education.

References

Amos, R. and Christodoulou, A. (2018) Really working scientifically: strategies for engaging students with socio-scientific inquiry-based learning (SSIBL). *School Science Review*, **100**(371), 59–65.

Levinson, R. (2011) How Science Works: teaching controversial issues. In *How Science Works*, ed. Toplis, R., pp. 56–70. London: Routledge.

Levinson, R., Hand, M. and Amos, R. (2012) What constitutes high-quality discussion in science? Research from the Perspectives on Science course. *School Science Review*, **93**(344), 114–120.

Romero-Ariza, M., Abril, A.M. and Quesada, A. (2018) Empowering teachers to bring authenticity and responsive action into the science classroom. *School Science Review*, **100**(371), 40–45.

Sadler, T.D., Klosterman, M.L. and Topcu, M.S. (2011) Learning science content and socio-scientific reasoning through classroom explorations of global climate change. In *Socio-scientific Issues in the Classroom*, ed. Sadler, T.D. pp. 45–78. Dordrecht: Springer.

Ralph Levinson is Reader in Education at University College London Institute of Education.
Email: r.levinson@ucl.ac.uk