Chapter 6
Learning About Youth Engagement in Research-Informed and Negotiated Actions on Socio-scientific Issues

Mirjan Krstovic

6.1 Reforming Science Pedagogy Through Research-Informed and Negotiated Activism

I started teaching ten years ago in one of the most populated, ethnically diverse and 'tech savvy' high schools in the Peel District School Board, the second largest school district in Canada. Like many beginner teachers, I learned to manage my classroom, establish daily routines, design mostly teacher-centred lessons, prepare 'recipe-style' lab activities, gain expertise and confidence with classroom technology, keep track of students' learning and perform a variety of other curricular and co-curricular duties. Different professional development opportunities at the school, district and provincial level triggered deeper critical thinking about my role as a twenty-first century science teacher and fuelled my passion for on-going professional growth.

My interest in processes of teaching and learning, education research and praxis inspired me to pursue a Masters of Education at the Ontario Institute for Studies in Education (OISE), University of Toronto. Many graduate courses, particularly the history, philosophy and sociology of science (HPSS) course taught by Larry Bencze, the editor of this book, encouraged profound reflection and discourse on dominant science pedagogy. I questioned if my students gained realistic conceptions about the nature of science and technology (NoST). Was I doing enough to encourage awareness of the complex interactions among science, technology, society and environment (STSE)? Were my students learning how to apply their scientific knowledge and skills in meaningful and purposeful ways?

I concluded that my early years of practice promoted mostly development of conceptual and theoretical knowledge, with one or two assignments that encouraged

M. Krstovic (✉)
Peel District School Board, Mississauga, ON, Canada
e-mail: mirjan.krstovic@peelsb.com

L. Bencze (ed.), *Science and Technology Education Promoting Wellbeing for Individuals, Societies and Environments*, Cultural Studies of Science Education 14,
DOI 10.1007/978-3-319-55505-8_6

students to make connections between science and other disciples. My past experiences resonated with readings in my graduate courses (e.g., Abd-El-Khalick & Lederman, 2000; Bencze & Carter, 2011; Crawford, 2007; Hodson, 2003), which suggest that school science systems compromise learning of STSE issues, stagnates development of science inquiry and misrepresents the nature of science and technology. I felt that many in-class activities, especially the labs, could be more *authentic* to allow for student-led, open-ended inquiries that are contextualized in real world applications. Actions to address STSE controversies never made it into my course plan until three years ago, when I began implementing research-informed and negotiated action (RiNA) projects in my tenth grade 'academic' science class.

After I completed a final research paper on school science reform in the HPSS course, I asked Larry if he could facilitate an action research project in my tenth grade 'academic' science class on students' progress of NoST knowledge. Larry agreed; however, he suggested that we should study students' expertise and motivation for self-directing RiNA on STSE issues, and that students' NoST views would relate to their actions. I was eager to begin our collaborative inquiry and learn about Larry's STEPWISE instructional framework.

STEPWISE offers an approach for STSE education that enables students to self-direct primary (e.g., correlational studies and experiments) and secondary (e.g., Internet searches) research as bases for developing and implementing plans of action to address a variety of socio-scientific issues. To help students to develop relevant expertise and motivation, we provide students (as reviewed in Chap. 2) with two successive 'apprenticeships.' This begins with 'basic' apprenticeship activities that first includes a teacher-guided project (e.g., I model student-led action projects), and moves towards a more 'advanced' apprenticeship that includes a second teacher-guided RiNA project (e.g., I guide students through secondary and primary research). After such guidance, students often are then ready to self-direct RiNA projects, in which they have opportunities to apply their learning. Derek Hodson (2014) supports the 'apprenticeship' model, stating that "students can gain experience of action, and thereby learn *through* action and learn *from* action, via the familiar 3-phase apprenticeship approach: modelling, guided practice and application" (p. 87).

I have had the privilege of observing various outcomes of an issues-based and action-oriented science education on students' academic and personal growth. This chapter offers some insights into the following three questions, which have guided my practice in ways that would allow my students to propose and implement research-informed and negotiated actions to address critical STSE issues in their school and community:

- What would our classroom look like, and feel like, if we let our students voice their opinions and positions on critical STSE issues?
- How do we set conditions in which students would be learning science and *doing* science in the context of real issues and gain a greater sense of purpose through education, other than merely earning grades?

- How do we equip our students with the capacity and commitment to take responsible and effective actions on matters of social and environmental and moral-ethical concern?

6.2 Building a More *Balanced* Science Curriculum

Science scholars and educational jurisdictions have been promoting STSE activities for over forty years (Pedretti & Nazir, 2011). With the latest elementary and secondary science curriculum revisions in Ontario, STSE education is given increased priority (MoE, 2008). With more attention to STSE education, students would develop a broader understanding of science; they would develop better critical thinking and decision making skills; and, they would be better prepared for active and responsible citizenship, now and in the future. Therefore, instructional frameworks that encourage exploration of socio-scientific issues are worthy of attention – given many serious social and ecological problems that humanity faces. This form of critical pedagogy is a more radical approach that politicizes science education, challenges dominant relations of power and positions students as agents of positive change in their schools and the wider community.

Experiences that encourage civic-mindedness, like socio-political activism in school science, are *authentic* learning phenomena that go beyond 'academic learning' (sometimes called 'book smarts'), which some students associate with boredom. I am not undermining the importance of 'academic learning' of scientific knowledge that underlies many important socio-scientific issues. Instead, I am suggesting that a more '*balanced*' approach to science education should triumph over the traditional 'concepts-mostly' education. Learning science (and technology) concepts should be balanced with *doing* science and technology, learning *about* science and technology, and *engaging* in socio-political action. Derek Hodson (2003) used these four broad learning domains to define science literacy, which is the overall aim of the secondary science programme in many jurisdictions.

Over the last 3 years, I learned that students can – and want – to make a difference in our world, and that a balanced approach is more equitable (Krstovic, 2014). Related to equity, we learned that RiNA promotes '*street smarts*,' the idea that practical intelligence and experiential education stand in contrast to traditional 'book smarts' (Chap. 13: Phillips, Krstovic & Bencze, this volume). This finding has implications to social justice, in that RiNA leads to increased participation of students who normally do not do well in traditional 'book smart' environments that seem to dominate many science classrooms. Having said this, many students are conditioned by traditional 'book smarts' environments that rely heavily on direct instruction, or what some call 'teach-test-teach' approaches. In this chapter, I discuss why some students experience difficulties with RiNA, and what factors contribute to student success.

6.3 Significant Theories and Philosophies That Have Inspired My Journey Through RiNA

While I was a graduate student in education, I learned about work of many transformative educators (e.g., Dewey, 1938; Foucault, 1991; Freire, 1970; Latour, 2005; etc.) whose theories have affected my practice and continue to shape my philosophy of education. Paulo Freire's (1970) *Pedagogy of the Oppressed* reaffirmed my belief that students should be co-creators of knowledge and not empty vessels waiting to be filled. According to Freire, if teachers wish to develop students' critical literacy skills, then they need to encourage students to question issues of power. I am drawn to Freire's ideas that students sometimes become teachers, that teachers and students construct knowledge together, and that together they interrogate significant life issues. I am the 'lead learner' in my classroom, and it is important for me that my students see me as a learner.

John Dewey's (1938) *Experience and Education* has made me think more critically about the learning experiences that I create for my students, or that students co-create with me, both inside and outside the classroom. Dewey (1938) asked several important questions about the 'character' of students' experiences in schools:

> How many [students] came to associate the learning process with ennui and boredom? How many found what they did learn so foreign to the situations of life outside the school as to give them no power of control over the latter? How many came to associate books with dull drudgery, so that they were 'conditions' to all but flashy reading matter? (p. 27).

Dewey's questions relate well to the present reality of twenty-first century school science. Teacher-centred, didactic and textbook driven methods may no longer meet the needs and reflect the experiences of our students. If we want to engage our students in learning processes, then the role of the teacher needs to change in response to the rapid changes in our society. Alsop and Bencze (2009) remind us that:

> [o]ur practices cannot afford to repeat the same experiments over and over again, mixing those same chemicals, when everything else has changed around us; we should not let our sphere of influence slip to a semi-historical re-enactment of our own educational experience – reducing our remit to efficiently covering dislocated facts and leaving all matters of concern to the politicians, the popular media and other moralizers (p. ii).

Science teachers should set conditions that allow growth in an 'experiential continuum,' which represents "the kind of present experiences that live fruitfully and creatively in subsequent experiences" (Dewey, 1938, p. 28). The stepwise nature of RiNA apprenticeships gradually builds experiences that allow students to develop knowledge, skills and attitudes required to understand and address STSE issues of their interest. This process is both continuous (i.e., extends throughout the course) and progressive (i.e., students' expertise and confidence grow with experience).

It is apparent that we live in a largely *neoliberal* capitalist society. Larry Bencze and Lyn Carter (2011) use Michel Foucault's (1991) notion of neoliberal *governmentality* to explain how people may believe that they are self-governed in this system, while

> [t]heir 'choices' may lack real agency and be fully congruent with aims of neoliberalism due to repeated exposure to messages from business-controlled news, sports, and entertainment media promoting such virtues as *individual responsibility, competition, excellence, efficiency, standardization, privatization,* and *commodification*" (p. 650).

School science (and technology) may be significantly influenced by the 'neoliberal pedagogy' that seems to promote practices that encourage individual competiveness (among other traits) and that advantage students who already possess considerable *cultural capital* (Bourdieu, 1986). Under this system, relatively few students with sufficient cultural and social capital reap benefits of such neoliberal education. By encouraging students to examine powerful networks, they learn to interrogate societal issues and challenge dominant power relations associated with various products and services of science and technology.

Related to students' understanding of dominant power relations, Larry Bencze introduced me to *Actor Network Theory* (ANT) (Latour, 2005). Students use ANT to explore living, non-living and semiotic 'actants' (or 'components,' as I refer to them in class) involved in everyday commodities. Students' understanding of various relationships among actants, through development of *actor-network maps*, allows students to consider new actants as they plan and implement their actions to address controversial issues (e.g., producing an activist video to address impossible standards of beauty set by popular media). Their actions become new 'actants' (or groups of actants) within the network that can challenge dominant semiotic messages by governing powers (e.g., students develop an activist video that challenges the idea that wearing brand name cosmetic products will make young women as beautiful as the models in popular magazines).

Increasing civic participation is good for a democratic society. Our young citizens should be involved in local, national and international decision-making. Hodson (2014) reminds us that:

> [b]y engaging in public issues at the local level, students see democratic process in action and learn how to engage in and negotiate them. By working alongside others, they learn about the demands and difficulties of taking action and learn to develop effective coping strategies. Research suggests that participation in these kind of activities in childhood and adolescence is associated with levels of civic participation, community service and political activism in adulthood up to four times higher than the norm (p. 86).

Students should not wait until they become adults to learn about civic engagement on issues that affect personal, social and ecological wellbeing. Where else, if not in our schools, can we train the most number of students to develop civic-mindedness? Research-informed and negotiated action projects represent one avenue for teachers and students to learn about the most pressing socio-scientific issues and ways in which we can collectively address them. Understanding of power, especially with the help of actor-network theory, will help increase students' capacity to take responsible and effective actions now, and in the future. The remainder of this chapter provides more specific examples of practices broadly described above.

6.4 'Basic' Apprenticeship Activities to Introduce Students to STSE Issues and RiNA Projects

6.4.1 The Card Exchange Game

Based on constructivist learning theories, students can benefit from exploring their pre-instructional ideas, attitudes and beliefs about STSE issues before learning about views of various stakeholders and developing (and hopefully implementing) actions to address problems that relate to the wellbeing of individuals, societies and environments (WISE). Previously, we have suggested a 'card exchange game' to help students explore a potpourri of STSE issues (Krstovic & Bencze, 2012). In this 'game, students evaluate various STSE issues by expressing their positions and sharing them with their peers. Teachers write one STSE issue per cue card (e.g., Governments should encourage development of nuclear energy). They distribute four, or more, different cue cards randomly to each student. The students play the 'exchange game,' trading statements with which they least agree with those about which they most agree. Students gain appreciation for various perspectives as they discuss current STSE issues with each other. Under teacher guidance, they start to think about possible actions or solutions in response to real world problems. We suggest this activity as a first step towards research-informed activism.

6.4.2 Exploring Controversial Statements: The Four Corners Tactic

The Four Corners tactic is one of my favourite techniques to get student to react to various controversies, prior to guiding them into the first research-informed action project. I label each corner of the room with 'strongly agree,' 'somewhat agree,' 'strongly disagree,' and 'somewhat disagree.' I project a controversial statement on the white screen. Students first think about the statement individually, then I instruct them to move to the corner that represents their opinion. For example, I share the following statement with my tenth grade 'academic' students: "*Be it resolved that governments should allow competing companies to decide how much greenhouse gases to emit each year*."

When the students get to their corners, they pair up, or form a group of three. The students have a few minutes to discuss their opinions with likeminded peers. A whole class discussion begins with a volunteer from each corner sharing his/her opinion. The teacher ensures that students' voices are heard by reinforcing active listening and paraphrasing. Judgement and debate are suspended in lieu of hearing different positions. Teacher can facilitate discussion around possible actions that citizens can take to minimize any negative consequences on individual, social and ecological wellness.

This activity can be repeated with another controversial statement. The activity takes about 15–30 min, depending on the level of student engagement with the statement. After I finish with this activity, I hand out a list of possible issues for the first RiNA project. Students form groups of three to four. They select an issue that interests them as they are more likely to develop deeper attachment and commitment to the project. What follows next is another stage of expressing pre-conceived ideas, but this time students brainstorm what they know in their groups using a place mat, mind map or another tactic. (Placemat tactic involves groups of students working both alone and together around a single piece of paper to simultaneously involve all members. Students may write or draw their ideas on a larger piece of paper that is divided into three or four sections, depending on the size of the group.)

6.4.3 Brainstorming Ideas About STSE Issues in Small Groups

Each science unit is accompanied by STSE issues suggested in the official secondary science curriculum document. Teachers can add more issues, if they wish. For example, this is a list of water-related issues that I gave to my eleventh grade 'university level' Chemistry students for their RiNA project in the Solutions and Solubility unit:

- Social, economic and environmental implications of using plastic water bottles
- Specific toxins present in water (e.g., industrial, pharmaceutical)
- Sanitation issues in developing nations/or in developed nations
- Privatization of water resources
- Oil spills and oil dispersants
- Water conservation technologies (e.g., roof tanks, etc.)
- Other…students suggest an issue related to global water supplies

Students begin by exploring what they already know. A placemat or a mind map can be used to demonstrate their collective knowledge and understanding prior to beginning any secondary research to learn more about the issue (see Fig. 6.1 for a student-generated mind map of oil spills and oil dispersants).

Teachers should offer some guidance to students as they start to express their ideas. For example, teachers may ask students to express positive and negative consequences on individuals, societies and environments associated with their issues. At this stage, teachers should encourage students to think about the positions of various stakeholders (e.g., governments, corporations, parents, youth groups, social and environmental activists, etc) and possible power relations.

Fig. 6.1 Students' mind map of their preconceived ideas about the impact of water sanitation issues on the well-being of individuals, societies and environments

6.4.4 Guiding Students into 'Secondary' Research

Research is challenging in the age of digital information overload, especially considering numerous networks associated with socio-scientific issues and myriad effects on individuals, societies and environments. Research is a skill that students acquire over time. Teachers could work with the teacher librarian to develop a lesson on conducting proper secondary research before the students access the Internet or other sources. One of the most important aspects of secondary research is confidence in the validity of information. Students need to be able to discern reliability of sources, like personal wikis, blogs, popular magazine articles, etc. Related to this, students need to learn to reference information properly in their final RiNA report using an appropriate format, such as the APA style. A list of questions helps guide the students through the secondary research for the first RiNA project, and for other activist projects in the course. I recommend the 5Ws+How sample questions in Table 6.1.

Students may be given two to three 75-min periods to work on their secondary research with their group. Students should divide work evenly to ensure fairness. Teachers should monitor students' research progress by setting deadlines and scheduling student conferences to discuss achievement. Evidence of progress and achievement should be collected throughout the project, and these data should be considered in teachers' professional judgement for the final evaluation. Students are also expected to put in additional time for the secondary research outside of the classroom.

Table 6.1 List of 5W+how guiding questions for secondary research

Question	Sample guiding questions
What	What is the issue? State the controversy clearly. Remember an issue has two sides – pros and cons – and it can be debated. What are the key science concepts that you need to know to understand the issue?
Who	Who are the key stakeholders and powerful decision makers? Who benefits and who might be harmed?
When	When has the issue become a concern for the well-being of individuals, societies and environments? Review the historical timeline, and perhaps, significant historical events that may coincide with the controversy
Where	Is the STSE issue of a local, national or a global concern? Is it specific to a region (e.g., the school, municipality, etc.)?
Why	Why should citizen learn about this issue?
How	How do we address some of the negative consequences associated with the issue? Think of possible actions that you might take to address the issue

6.5 Challenges of Contextualizing Learning of Science Concepts

Since most RiNA projects are unit-specific, although they do not need to be, it follows that specific science concepts can be contextualized in various socio-scientific issues. For example, when students learn about functions of major organs and organ systems, teachers can help relate functions of the organs to specific issues. For example, consumption of high sugar foods can impact one's pancreatic function and lead to various health concerns, such as diabetes and obesity. Sometimes, the concepts that teachers are required to teach may not directly relate to the issue(s) that the students are studying. For example, the major focus on the tenth grade 'academic' curriculum in the Chemistry unit is on chemical reactions. However, the RiNA project that I facilitate is based on personal hygiene and beauty products. There is no *immediate* connection between the types of chemical reaction, balancing, and the law of conservation of mass, for example, and effects of everyday commodities on wellbeing of individuals, societies and environments. However, each commodity (e.g., shampoo, soap, deodorant, etc.) involves a series of complex chemical reactions that sometimes use controversial chemicals with possible undesirable effect on WISE. In this case, the big idea that teachers need to convey is that chemical reactions may have negative impacts on individuals, societies and environments. Students' actions should be targeted towards potentially negative effects of such commodities. These effects do not necessarily need to be related to the chemicals inside the products. The negative effects on WISE can be related to incredulous claims by advertisers, unethical testing of a product on animals, unfair wages paid to workers (often in poor countries), improper disposal of waste, and many other social and ecological justice issues.

In addition to acquiring knowledge and understanding of science concepts relevant to the issue, students need to learn about complex interactions among science and technology with society and environment. For example, throughout the RiNA learning cycle, students should consider individual health concerns, economic impacts, various ethical and moral considerations, political decision-making, corporate motives, power relations, media's influences, and various ecological concerns related to the issue of their interest.

6.6 'Advanced' Apprenticeship Activities to Facilitate Application of Actor Network Theory to RiNA

A year and half into my work with RiNA, I started to infuse actor-network theory to help students develop 'a big picture' view of the issues by considering various living, nonliving and semiotic actants related to their STSE issues (Pierce, 2013). Although I am still learning how to best introduce students to this complex theory without overwhelming or confusing them, a few strategies have worked relatively well. The secondary research that students compile should help them identify various actants, although teachers need to explicitly model this. The objective is to construct an actor-network map to show the co-dependence of many actants (watch videos in Fig. 6.2 for examples of students' actor-network maps). Infusion of actor-network theory would be considered a more 'advanced' apprenticeship activity, as it pushes higher order thinking skills such as critical analysis of networks and evaluation of actants' alignment to support dominant semiotic messages. Teachers should not name the theory. They should keep the language simple and easy for students to understand. We discuss the findings of our research into ANT in Chapter 9. Here, I outline some practical strategies that I use to help infuse ANT into RiNA.

Fig. 6.2 QR codes to two videos in which: (i) I discuss the actor-network map about 'smart phones,' and (ii) students discuss their network maps illustrating relationships among various entities connected to different consumer products

6.6.1 Trojan Horse Metaphor for Teaching Students About 'Hidden' Actants

The Trojan horse metaphor is a powerful analogy that can be used to help students understand that there is more to everyday commodities (e.g., cell phones, computers, cosmetics, pesticides, water bottles, toys, etc.) than what our eyes see. Colourful packaging, enticing ads, 'sexy' designs, feel-good messages, and other external features and semiotic messages can occlude potentially negative effects associated with certain products and services of science and technology.

In my tenth grade 'academic' science class, the students analyze and evaluate some of the potentially negative impacts of personal hygiene and beauty products on wellbeing of individuals, societies and environments. As part of the 'basic' apprenticeship prior to conducting secondary and primary research, I bring to the class several hygiene products and ask the students how these products might be like a Trojan horse. Students brainstorm some positive and negative effects of various products (e.g., shampoo, deodorant, lip balm, etc.) and a whole class discussion follows about some 'hidden' components. I extend students' thinking beyond just the chemicals inside the product and their effects on health, which is what students first consider. I ask questions like: 'Where do these raw materials come from?,' 'Who extracts the raw materials?,' 'Where are they extracted?,' 'What is the packaging made of?,' 'How is the product marketed?,' 'What features of this product make it attractive for the buyers?,' 'How is the product disposed?,' etc. The students start to consider the 'big picture' and various living, non-living and semiotic components. These questions serve to guide students' thinking and they set the stage for *The Story of Stuff* video by Annie Leonard.

The Story of Stuff video takes students through the life cycle of a product from extraction of raw materials to production, distribution, consumption and disposal. The video is useful to show when the STSE issues relate to everyday commodities. As students watch the video, they record significant points about each stage. The teacher discusses key ideas with the class after the video. The discussion should be framed in the context of actor-network theory by asking questions such as: 'What are some living components in each stage (e.g., miners, factory workers, truck drivers, animals, plants, etc.)?,' 'What are some non-living components (e.g., raw materials, technologies, etc.)?,' and 'What might be some semiotic messages associated with each stage (e.g., miners' work feels dangerous, the product makes you feel 'trendy,' 'sexy,' etc.)?' Teachers should help students develop some understanding of negative impacts on 'WISE' resulting from each stage in the life cycle of a product.

Together with the Trojan horse metaphor and *The Story of Stuff* video, students gain an appreciation of some 'hidden' components/actants associated with everyday commodities and controversial STSE issues. This prepares them well for using their secondary research to construct a study for their 'primary' research and to inform their action plans.

6.6.2 Modelling Construction of a Network Map for a Cell Phone

Teachers should model creation of an actor-network map. After the students watch *The Story of Stuff* video, I pick an everyday product, such as a cell phone. I start constructing a network map showing different actants associated with this product (Scan the QR codes in Fig. 6.2 to view the videos of an actor-network map and students working on their network maps for various consumer products). I engage the students in creation of the network map by asking them to name the components of the cell phone that they see. Our discussion moves to components that we do not see, but that are part of the cell phone (e.g., Coltan miners, phone engineers, corporations that employ the engineers, advertisers and marketers, drivers who distribute the product, technology used to assemble the phone, consumers who buy the product, cost of the product, etc.). The students see how I connect various components and how each component (or actant) is co-dependent on other actant(s). For example, miners cannot mine without technology, and technology allows extraction of raw materials without which a phone (or another product) cannot exist. Additionally, I highlight components that may align to support the dominant semiotic messages. For example, I circle human organizations that encourage positive feelings associated with cell phones. I circle with a different colour living and non-living components that 'suffer' for us to have cell phones (e.g., miners, exploitation of Earth's natural resources, threatened species, etc.). The final network map serves as an exemplar for students to construct their own network maps.

6.7 Apprenticeship Activities for 'Primary' Research

6.7.1 'Basic' Apprenticeship Activities: Helping Students Understand Correlational Studies

An aspect of science inquiry that often does not receive enough attention in high school science is use of correlational studies – as opposed to experiments – for attempting to understand phenomena in nature. Correlational studies are inquiries in which investigators try to find relationships between variables that change *naturally*. Experiments, on the other hand, require that the investigator forces an independent variable to change and then measures changes in the resulting dependent variable. There is an apparent bias in science education towards experimentation and away from correlational studies (Bencze, 1996). Curriculum guidelines, as well as science textbooks, emphasize the experimental nature of science through the 'scientific method' (Gott & Duggan, 1995). However, experiments are not always ideal when students are asked to explore STSE issues. With correlational studies, unlike experiments, the choice to induce potentially negative outcomes (e.g., cancer) would not be in the hands of the investigator but, rather, be left to others (e.g.,

Table 6.2 Exercise for developing students' understanding of studies vs. experiments

Cause variables	Result variables
Vegetarianism	Teenagers' hearing
Rock music	Teenagers' learning
Exercise	Plant height
Hormones	Yeast fermentation
Drugs	Aggressive behaviour
T.V. watching	Physical fitness
Temperature	Muscle strength

smokers). We learned that students' results and conclusions from correlational studies can be used to inform activism to address STSE issues (Krstovic & Bencze, 2012). But students need a proper introduction and guidance to these types of science inquiries as they embark on the first RiNA project.

Teachers need to introduce students to correlational studies through various apprenticeship activities before the students conduct their own studies. Teachers should start by sharing examples of correlational studies while contrasting them with experiments. For example, when studying effects of smoking on lung cancer, it would not be ethical to force any group of people to smoke and determine if they develop lung cancer in comparison to non-smokers. Teachers would explain to students why a correlational study is more appropriate in this case. As an extension to this example, teachers can give students a list of 'cause' (independent) and 'result' (dependent) variables (see Table 6.2) and ask the students to match one cause variable to one result variable. Students should come up with five examples of correlational studies and two examples of experiments. For example, students can match T.V.-watching with teenagers' learning as an example of a correlational study, and temperature with yeast fermentation as an example of an experiment. Teachers should probe for deep understanding by asking students to justify why a correlational study or an experiment is most appropriate for each matched pair of variables. In both correlational studies and experiments, it is important to discuss control variables.

As a follow-up exercise, teachers can ask students to decide if they would conduct a correlational study or an experiment in several inquiry cases, such as these:

- Different types of light on the growth of a plant
- Time spent in front of the computer and quality of sleep
- The effect of pH on the amount of corrosion
- One's gender and their reaction rate

Students can justify their method of choice in small groups, and the teacher can take up each case with the whole class before guiding the students into a mini correlational study as a form apprenticeship activity prior to conducting a study for the first RiNA project. In terms of timing, one class period is sufficient for the above exercises, followed by another 75 min period to guide the students through a mini in-class correlational study.

6.7.2 Guiding Students Through a Mini Correlational Study

A purpose of guiding students through a mini correlational study is to engage students in small-scale data collection and analyses. For example, students can determine if there is a correlation between gender (independent variable) and one of the following dependent variables: preference between meat or veggie diet, reaction time, memory, tongue rolling ability, resting heart rate, extracurricular involvement in school, favourite school subject, etc. Gender is an easy choice of independent variable for a class with about equal boys to girls ratio; however, it is not a continuous variable, and therefore, students are limited to producing bar graphs only. Also, if the class is too small, teachers could give students ready-made data to analyze and evaluate. An important part of the discussion with students should focus on 'bias,' 'validity,' and 'reliability' of the results. Students need to understand that their mini study is biased, and that in order to increase the validity and reliability of their results, students would need a larger sample size and, if possible, repeat their study several times.

6.7.3 Preparing a Correlational Study for the First RiNA Project

With the abovementioned apprenticeship activities, students should be prepared to design a small correlational study for their first RiNA project. Students will require the teacher's guidance and facilitation to select questions for the survey and to analyze the data. As mentioned earlier, gender, age, and grade level are easy independent variables to select. Age and grade level are continuous variables and will allow for a line graph instead of a bar graph. But teachers should encourage students to explore a range of variables suitable to their STSE issue.

Selecting 'good' questions to put on surveys is one of the first challenges students face. Teachers should show a sample of study questions, like the one below (See Fig. 6.3). Students should conduct some secondary research prior to designing their studies as this helps with the selection of questions for the survey.

Students should have about four or five questions to allow enough time to analyze the results. Teachers should encourage students to divide the work evenly in their group. Students collect data in their classes or during lunch time. Usually, two days are sufficient for students to collect all the data. There may be one or two groups that might need extra time. Teachers should use their discretion when deciding how much time to give students for data collection and analysis. I ask students

Grade 10 Climate Change Correlational Study

1. Are you male or female? ☐MALE ☐FEMALE

2. What mode of transportation do you use most often to get to school?
   a) Bus b) Car c) Bike d) Walk

3. What kind of food do you prefer to eat most often?
   a) meat b) vegetables c) meat and vegetables

4. How often do you eat out at fast food restaurants?
   a) once a month b) once a week c) twice a week
   d) more than two times per week

5. What source of water do you drink most often?
   a) tap water (filtered or not filtered) b) bottled water

6. How long do you shower for on average?
   a) 0 to 5 minutes b) 5 to 10 minutes c) 10 to 15 minutes
   d) 15 minutes or more

Fig. 6.3 Sample survey for a tenth grade climate change correlational study

to collect and tally the data on their own time, and I give them one class period to graph the results. I check their progress on agreed-upon dates and I conference with students regularly, especially with groups that might be experiencing challenges.

6.7.4 Modeling Different Forms of Activism

Modeling different ways in which citizens can engage in activism is of paramount importance. Students can be motivated and inspired when they hear about activist work by teenagers and others in their community. Table 6.3 lists some examples that I share with my students.

Activism is not only about organizing rallies, protests and chaining oneself to a metal post. It is a type of public action that takes many different forms, such as

- collecting petitions to ban the sale of energy drinks to Minors
- writing letters to the editors of local or national newspapers and magazines
- developing and posting educational YouTube™ videos
- lobbying the school administration and teachers to save energy
- organizing games in school to encourage more recycling
- promoting a ‘Walk/Bike to School Day’
- planning and implementing new technology designs that consider social and ecological justice issues, etc.

Table 6.3 Examples of actions that I show to my students to model different forms of activism

Title	Web address/QR code	Description
Teens Against the Privatization of Water	http://tapthatwater.tumblr.com	Teens raise awareness of the impacts of bottled water and water privatization
TEDxTeen – Natalie Warne – Anonymous Extraordinaries	http://www.youtube.com/watch?v=FszSc7Fb8ss	As a volunteer for Invisible Children, Natalie Warne talks about her journey to expose Africa's longest running war involving child soldiers
TEDxSIT – Sam Stevens – Moving Youth Towards Action and Activism	http://www.youtube.com/watch?v=ALqzWs9gjGI	Sam Stevens has participated in various youth activism project both locally and globally. This video will motivate youth to use their education for make this world a better place for all
Piano stairs – TheFunTheory.com	http://www.youtube.com/watch?v=2lXh2n0aPyw	How do we get more people to take the stairs over the escalator? The Fun Theory suggests that 'the easiest way to change people's behaviour for the better is by making it fun to do.'
The Life Cycle of Foundation	http://www.youtube.com/watch?v=WhN6PS1GT9c	This student developed YouTube™ video exposes and educates the viewers about some hidden actants in cosmetic products

Proposing and implementing actions is probably the most exciting and memorable part of RiNA projects. Students are also motivated by what they hear and learn from their peers. Two years ago, one of my Grade 10 students commented in an interview that:

> [T]hese projects are more fun because you get to do more, when something is more fun you will remember it…Social awareness, I think that's what makes people remember it [the STSE issue] the most, hearing it from a friend you're more likely to listen than hearing it from your parents or reading it in a book (Student interview, April 2013).

I am pleased to hear that students associate the learning process with fun and not boredom, and that they learn from each other as they become young activists.

6.8 Celebrating Successful RiNA Projects and the Publication of Youth Issue of JASTE

Over the last 3 years, I have seen a number of successful RiNA projects that have benefitted students, societies and environments. A collection of ten successful projects was published in the first youth issue of the *Journal for Activist Scienceand Technology Education* (JASTE). The on-line journal is available at bit.ly/1t3B4XI or simply scan the QR code below (Fig. 6.4). This publication is a celebration of students' commitment, responsibility and solidarity to make the world a better place. JASTE is also an important actant that may bring about fundamental changes in science and technology education. Hopefully, more teachers will re-position science education as a vehicle for social and environmental transformations.

Although I have seen many great projects, two are worthy of mentioning here: 'No Car Day,' and 'Concerns over X-rays.' Both of these projects resulted in a positive contribution to the community and increased student confidence.

6.8.1 'No Car Day:' Reducing Our Carbon Footprint

A group of three students learned that transportation contributes the most carbon dioxide to our atmosphere. They learned about the impacts of climate change on wellbeing of individuals, societies and environments. The students identified powerful actors, such as oil companies and governments, which support uses of fossil fuels. They also learned about groups that oppose the use of fossil fuels and researched alternative energy sources.

After conducting some secondary research, the students conducted a study to determine if there is a correlation between gender and modes of transpiration. They found that 57% of students come to school by a car with no significant difference between genders. They also counted number of cars that dropped off students in the morning prior and post their proposed action.

Fig. 6.4 QR code to the first youth issue of the *Journal for Activist Scienceand Technology Education*

In response to their research, the students created posters to promote a ‘No Car Day’ at the school. They stood in the parking lot in the morning and after school with the signs to encourage parents and students to use public transportation, carpool, bike or walk to school. They counted 156 cars before their action, and 115 on the ‘No Car Day’ event. The students felt that they made a small difference in helping to reduce the carbon footprint of the school.

6.8.2 Concerns over X-rays

A group of four girls in grade 10 ‘academic’ science learned about X-rays as one type of medical imaging technology. They researched advantages and disadvantages of this technology, focusing on how often doctors prescribe them and amounts of radiation released for certain areas of the body. One student wrote the following in her final research report: “[W]e discovered while researching that teenagers tend to receive the highest amount of X-rays in a year, which is why we have decided that teenagers should be our target audience” (Student Report, 2014). The same student reflected on her personal experience:

> I had six X-rays in total for the one injury all within six weeks. Doctors still insisted that I go for three more X-rays even though I knew nothing would be found. Finally after nine X-rays of the same hand, I was sent for a different procedure which found the solution… Having too many X-rays can make you sick especially at a young age (Student Report, 2014).

For their primary research, the girls designed a simple study asking their peers three questions:

(i) Have you had any X-rays in the past three years? If yes, what part of the body?
(ii) Are you aware of the amount of radiation released by X-rays?
(iii) What part of the body received the greatest dose of radiation? ~Arm ~Foot ~Dental ~Pelvis ~Skull ~Abdomen (liver level) (circle one)

The girls learned that about equal number of boys and girls (19/30, and 17/30, respectively) had X-rays within the last three years. Dental, arm and leg were the highest X-rayed body parts for both genders. Almost all surveyed boys and girls were unaware of the level of radiation exposure, with most believing that skull would receive the highest amount of radiation.

For their action, the group wrote a letter to the Head of Diagnostic Imaging at a local hospital informing the doctor about their research. They received a two-page reply from the doctor, who thanked the girls for their detailed inquiry, and who wrote in his letter: “I applaud your efforts to educate yourselves, your students and your community and I look forward to statistically lower dose rates in the future as patients become more educated and involved in their healthcare and I thank you for your role in contributing to this.”

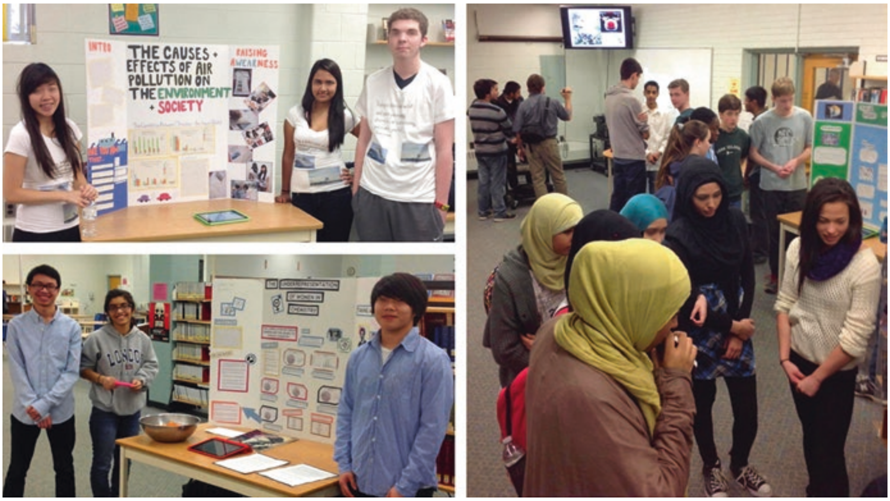

Fig. 6.5 Sample photos from the first STSE fair with the Grade 11 University level Chemistry students

6.8.3 Organizing an STSE Fair at the School

We are all too familiar with science fairs, at which students showcase their projects and judges evaluate their work based on pre-determined criteria. But rarely, if ever, has anyone organized a fair to showcase students' research-informed and negotiated action projects. The setup of an STSE fair resembles a 'traditional' science fair, but on a closer look, students' displays do not necessarily follow the rigid 'scientific method.' Instead, students explain controversies surrounding their issues, display actor-network maps, present results of their correlational studies, show their ready-to-use action materials and discuss the impact and effects of their implemented actions.

I organized the first STSE fair in the school library and invited several classes to visit, one at a time (See photos in Fig. 6.5). Teachers and students visited students' displays and asked questions about the projects. Handing out a list of questions to the visiting classes may be a good idea to prepare students and increase accountability for participation. If more teachers decide to run STSE fairs, the main foyer or the school cafeteria could be excellent settings for these events. I encourage teachers to organize similar events at their schools.

6.9 Factors That Contribute to Successful RiNA Projects and the Related Impacts on Students' Academic and Personal Growth

Student success with the RiNA projects depends on myriad factors. I identified the following factors as the most important in helping the students achieve success:

- students' (and teachers') sustained interest and motivation to learn about contemporary socio-scientific issues
- students' positive and productive group dynamics
- teacher's knowledge and skills in guiding students through apprenticeship activities and collaborative work
- opportunities for students to self-direct their research and actions
- students' explicit cycles of reflection on the nature of research and actions

We discuss the last two factors in more detail in the eighth Chapter. These six factors are mutually dependent. Teachers play a central role in helping students understand and develop expertise and confidence in conducting research-informed and negotiated activist projects.

I learned from my unsuccessful groups that students' lack of success resulted from their lack of understanding of the purpose of RiNA. It would be unrealistic to say that all students enjoy these projects and that they are all equally successful. Some students prefer direct instruction, recipe-style labs and individual projects, which all serve a purpose. But the students' roles in the tradition-bound science classroom is different from students' roles in a more student-led, open-ended and collaborative environment. Teachers' guidance towards greater student autonomy for conducting RiNA may require explicit discussion with students about purposes of RiNA projects, their place in the science curriculum and students' expectations and factors that contribute to success. Parents should also be informed about these learning activities.

Outcomes of student-led research-informed and negotiated actions on socio-scientific issues are vast. I have observed students who continue to be engaged in activist projects and leadership activities beyond the classroom. After his 'No Car Day' event at the school, one student ('Robert') led a group of 40 students for the World Vision 30 Hour Famine event. The students raised over $400 for World Vision. Robert started the Interact club at the school for his peers who want to tackle the issues in their community and internationally through various service projects. He explains that RiNA projects in Grade 10 inspired him to continue to make a positive difference in his school and the community. I am proud of students who use their activist science education to develop into young leaders that strive to make this world a better place for all.

6.10 Moving the System Forward: Promoting Issues-Based and Action-Oriented Science Curriculum

I have been a persistent learner in every setting in which I have worked. In many cases, I have taught 'against the grain' and stayed optimistic despite resistance. As one might imagine, school and/or system wide change comes slowly. One of the keys to change is building a collaborative climate in which everyone pursues change together. And this is precisely what I have been doing over the last four years. I started to promote issues-based and action-oriented science education by first working with a small group of teachers, one or two, in my science department to build their instructional capacity and professional efficacy. After I had left the first school in which I worked, teachers continued to implement issues-based and action-oriented curriculum. One of the teachers I worked with went on to become the department head of science at another school where she promotes RiNA projects with her science staff. In addition to working with small groups of teachers, I have promoted RiNA projects at various district and provincial conferences (e.g., Science Teacher's Association of Ontario conference, my school district's Environmental Education Conference, and my school district's Social Justice Innovation Day, etc.). However, sometimes it is difficult to measure the exact impact of these presentations on teachers' practice. With the recent publication of the JASTE issue, each high school in the my district received a hard copy of the journal. The journal serves as an actant to promote activist projects for social and ecological justice in science. To recognize the importance of social and environmental activism, I have initiated an award at my school called "Action for Social and Ecological Justice Award" to recognize students who make positive contributions to the community through their RiNA projects. Most recently, I have invited Larry Bencze as the Keynote speaker at my school district's first Science and Technology Inquiry Symposium, at which he spoke about application-based inquiry. We are in the process of initiating a 'STSE Controversy and Political Actions' group in with elementary and secondary teachers who are interested in embedding social and environment justice issues in their classes. We are creating a positive movement with the support from several system leaders in the district. I am excited and motivated by the impact that we can have as we engage and empower our students to take actions on contemporary socio-scientific issues. I feel confident in our ability to galvanize change and I am humbled by the possibilities of a more active and politicized science education.

References

Abd-El-Khalick, F., & Lederman, N. G. (2000). The influence of history of science courses on students' views of nature of science. *Journal of Research in Science Teaching, 37*, 1057–1095.

Alsop, S., & Bencze, L. (2009). Editorial: Beyond the confines of matters of fact. *Journal of Activist Science and Technology Education, 1*(1), i–v.

Bencze, J. L. (1996). Correlational studies in school science: Breaking the science-experiment-certainty connection. *School Science Review, 78*(282), 95–101.

Bencze, J. L., & Krstovic, M. (2013). *Students' social studies influences on their socioscientific actions*. A presentation at the annual conference of the American Educational Research Association, San Francisco, CA, April 27–May 1, 2013.

Bencze, L., & Carter, L. (2011). Globalizing students acting for the common good. *Journal of Research in Science Teaching, 48*(6), *648–669*.

Bourdieu, P. (1986). The forms of capital. In J. G. Richardson (Ed.), *The handbook of theory: Research for the sociology of education* (pp. 241–258). New York: Greenwood Press.

Crawford, B. A. (2007). Learning to teach science as inquiry in the rough and tumble of practice. *Journal of Research in Science Teaching, 44*(4), 613–642.

Dewey, J. (1938). *Experience and education*. New York: Collier/Macmillan Press.

Foucault, M. (1991). Governmentality. In G. Burchell, C. Gordon, & P. Miller (Eds.), *The Foucault effect: Studies in governmentality* (pp. 87–104). Hemel Hempstead, UK: Harvester Wheatsheaf.

Freire, P. (1970). Pedagogy *of the oppressed.* New York: Continuum.

Gott, R., & Duggan, S. (1995). *Investigative work in science curriculum*. Buckingham, UK: Open University Press.

Hodson, D. (2003). Time for action: Science education for an alternative future. *International Journal of Science Education, 25*(6), 645–670.

Hodson, D. (2014). Becoming part of the solution: Learning about activism, learning through activism, learning from activism. In J. L. Bencze & S. Alsop (Eds.), *Activist science and technology education* (pp. 67–98). Dordrecht, The Netherlands: Springer.

Krstovic, M. (2014). Preparing students for self-directed research-informed actions on socio-scientific issues. In L. Bencze & S. Alsop (Eds.), *Activist science and technology education* (pp. 399–417). Dordrecht, The Netherlands: Springer.

Krstovic, M., & Bencze, J. L. (2012). Using a 'card exchange' game to help students explore STSE issues. *Crucible Online, 43*(3), 1–8.

Latour, B. (2005). *Reassembling the social: An introduction to actor-network-theory*. Oxford, UK: Oxford University Press.

Ministry of Education [MoE]. (2008). *The Ontario curriculum, grades 9 and 10: Science*. Toronto, Canada: Queen's Printer for Ontario.

Pedretti, E., & Nazir, J. (2011). Currents in STSE education: Mapping a complex field, 40 years on. *Science Education, 95*(4), 601–626.

Pierce, C. (2013). *Education in the age of biocapitalism: Optimizing educational life for a flat world*. New York: Palgrave Macmillan.