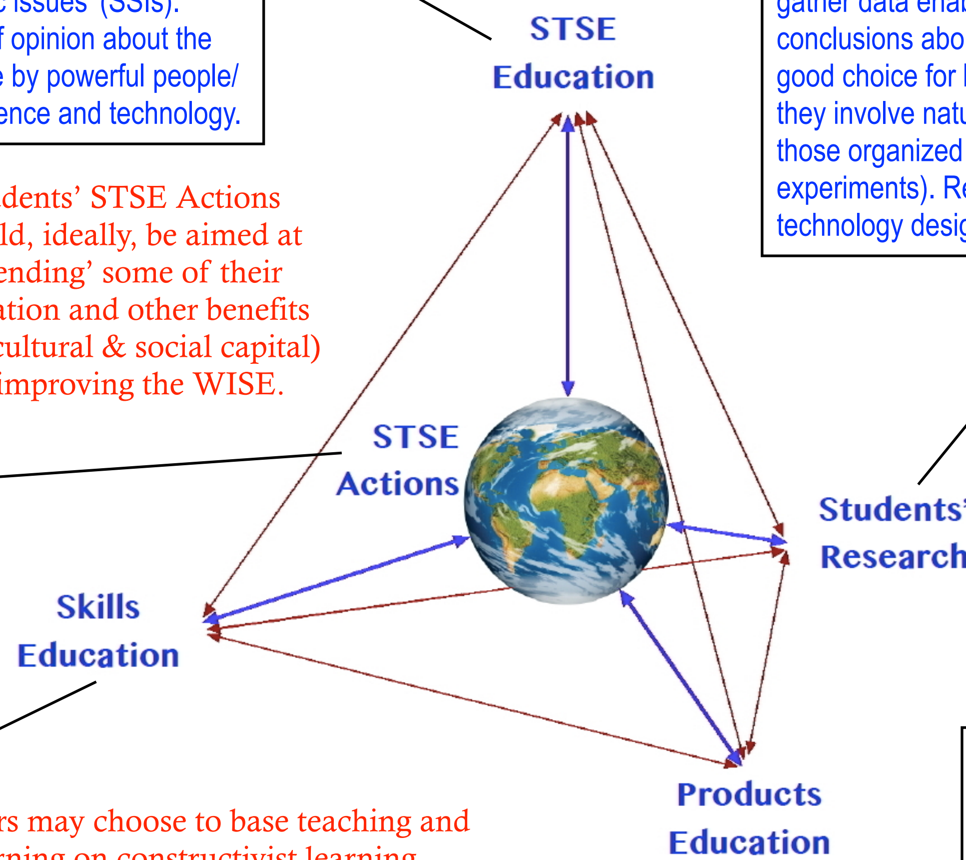
'STSE' refers to relationships between fields of science and technology and societies and environments. It encompasses the nature of science and technology (NoST) - as well as the nature of societies (e.g., sociology) and environments (e.g., ecology). Some STSE relationships, such as that progress in science often depends on progress in technology development, are relatively neutral. Others may be, to varying degrees, contentious. Potential harms to the wellbeing of individuals, societies and environments (WISE) are sometimes called 'STSE Issues' or 'socioscientific issues' (SSIs). Common SSIs appear to stem from differences of opinion about the benefits or harms to WISE due to decisions made by powerful people/groups about purposes, methods and uses of science and technology.

STSE Actions (rather than any of the other domains) are placed in the centre of the tetrahedron to emphasize needs for citizen actions on the many possible harms to WISE.

'Students' Research' refers to research directed by students, also allowing them to arrive at their own conclusions based on findings, theories and other factors (e.g., peers' positions). 'Secondary' research might include Internet or library searches, for example, or interviews of 'experts.' For 'primary' research, students might design and conduct experiments or studies (e.g., correlational and/or qualitative studies) to gather data enabling them to draw their own conclusions about phenomena. Studies often are a good choice for learning more about SSIs because they involve natural changes in variables - rather than those organized by the investigator (as with experiments). Research may follow ore precede technology design, depending on student choice.

Students' STSE Actions should, ideally, be aimed at 'spending' some of their education and other benefits (e.g., cultural & social capital) on improving the WISE.

'STSE Actions' may include one or more of: *educating others* (e.g., via posters, websites, etc.); *lobbying 'power-brokers'* (e.g., letters to companies, government); *preventing potential harms* (e.g., blockading company vehicles); *making personal changes* (e.g., recycling); or *designing more socially just and/or environmentally sustainable technologies*.



The double-headed arrows indicate that there are reciprocal relationships between learning and acting in all domains; e.g., Products Education depends on Skills Education.

'Skills' include, for example, *cognitive* (e.g., designing studies, designing graphs), '*psycho-motor*' (e.g., measuring, drawing, making graphs), *interpersonal* (e.g., debating); and *affective* (e.g., controlling emotions) skills.

Teachers may choose to base teaching and learning on constructivist learning principles; e.g., first asking students to express pre-instructional attitudes, skills and knowledge ('ASK') about one or more of the domains here (e.g., Skills Education and STSE Actions), then teaching them some useful ASK about these, finishing with students' opportunities to determine their beliefs about specific domains.

Because of the reciprocal relationships among all domains above (e.g., Skills Education), students could begin at any domain and consider any other domain(s).

'Products' include laws and theories and ideas about inventions/innovations from fields like: biology, chemistry, physics, geology, mechanical engineering, chemical engineering, biotechnology, astronomy, etc. Products may include those from different cultures, including 'mainstream' professional science and technology, but also sub-cultures like Indigenous Knowledge from different parts of the world.

Unit 1 Climate Change	Unit 2 Light & Optics	Unit 3 Chemical Change	Unit 4 Intro. Physiology

——> [Products Ed'n ↔ STSE Ed'n] ——>

A common use for STSE issues is to use them as meaningful contexts for motivating students to learn 'products' (e.g., laws & theories) of science and technology. A common method for doing this is to have students read through case documentaries of STSE issues and answers questions requiring them to learn various products - with through their secondary research or through teacher instruction or both.

when students are ready

Students Express STSE Issues & RiNA

Teachers Teach RiNA Projects

RiNA Apprenticeships (Teacher-guided)

Teachers Guide Students' Mini-RiNA Projects

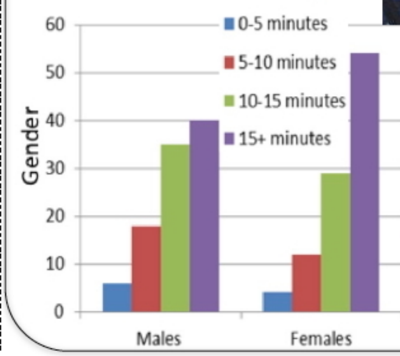
'RiNA' = Research-informed & Negotiated Action(s)

www.stepwiser.ca

Student-led Actions
e.g., Posters
e.g., Letters
e.g., Petitions
e.g., Protests
e.g., Videos
e.g., 'Green' Tech
e.g., Blockades

Students' RiNA Projects (Student-led)

Teens' Shower Lengths



Student-led Research
e.g., Web Searches
e.g., Correlational Studies
e.g., Interviews

Teachers find that it is difficult to implement the tetrahedral form of STEPWISE; since it allows each student to consider different domains at once. Teachers prefer the more linear framework at left because students often lack backgrounds for it and benefit from structured teacher-led lessons and activities prior to self-directing their own RiNA projects.

A central STEPWISE goal is to have students lead research-informed and negotiated action (RiNA) projects to tackle socio-scientific problems of interest to them. Students must get to the point that they no longer need the teacher or any other authority figure in their roles as citizens taking actions for the common good.

For many students, who have rarely been asked to conduct primary research or take socio-political actions in their schooling, they benefit from one or more sets of 'apprenticeship' activities. As shown above, teachers may need to repeat these - hopefully at a higher level of complexity - over at least two units. These apprenticeships are based on constructivist learning theory - which posits that individual learners construct unique conceptions by combining pre-instructional notions in their brains with stimuli (e.g., sights, sounds) from their learning environments. Many of their pre-instructional conceptions are subconscious. If teachers ask students to express their pre-instructional conceptions (e.g., of STSE Issues & RiNA projects), students may become more conscious/aware of them. They can then compare them to conceptions taught to them (e.g., sample RiNA projects). Students can then conduct mini-RiNA projects to gain expertise and confidence with such projects. In the first apprenticeships, the teacher may have provide students with more guidance than in the second (and, maybe, third) set of apprenticeship

Our research using the above framework suggests these (and other) conclusions:

- students' local correlational studies can motivate them to take local socio-political actions;
- asking students to reflect on the nature of STSE issues and RiNA projects after the first apprenticeship can improve later projects; and,
- students' RINA projects can be greatly enhanced if they are taught to make actor network maps of their STSE issues.

J.L. Bencze, 2014