STEPWISE: Implementation Suggestions from Action Research

=========================== INTRODUCTION ===========================

STEPWISE (Science & Technology Education Promoting Wellbeing for Individuals, Societies & Environments) is a framework for organizing teaching and learning to help students understand how powerful people and groups may influence fields of science and technology and societies and environments in ways that are associated with harms (e.g., cancer, species losses, climate change) for wellbeing of individuals, societies and environments and to develop expertise, confidence and motivation for designing and conducting research that may generate findings that lead them to develop and implement personal and social actions to address harms that are important to them. Since 2006, teachers and other educators have used this framework to develop and implement lessons and student activities and, during that time, data (e.g., samples of teacher lessons and completed student activities) have been collected and analyzed to try to understand factors influencing students' expertise, confidence and motivation for such critical and activist science education. This document provides a brief summary of some major findings from this action research.

========= BACKGROUND =========

As depicted in Figure 1, fields of science and technology ('STEM,' if engineering & mathematics are included) have many different relationships with each other and with other members of societies and living and nonliving environments. Although many of these are considered positive, such as medical knowledge and technologies that have prolonged human lives, many people are concerned about harms to individuals, societies and/or environments that have been linked to STEM fields. These include: illnesses from manufactured foods; death and destruction from weapons; privacy invasions using electronic surveillance and climate change from fossil fuel burning. Although there may be many reasons for such harms, including unintentional ones, there is much concern that actions of many wealthy people and groups (e.g., financiers & corporations) to control governments, STEM fields (e.g., see: goo.gl/rnKi3W), education, international trade, etc. and, in doing so, enrich themselves (e.g., Oxfam says 8 white men now have wealth equal to about 3.6 billion people) have contributed greatly to many of these harms. Consequently, many scholars, educators and others suggest that science (and/or 'STEM') education needs to educate citizens about such harms and be ready and willing to take informed actions to address those that most interest/concern them.

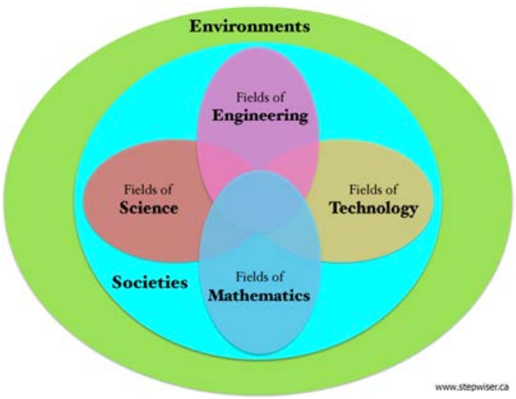

Figure 1: ST(EM)SE Relationships.

========================== STEPWISE PEDAGOGY ==========================

To help teachers to educate students about problems in ST(EM)SE relationships and develop and conduct informed personal and social actions to address harms they perceive in them, many teachers have been encouraged to base their lessons and student activities on the framework in Figure 2. The main goal is to help students develop expertise, confidence and motivation to self-direct (SD/OE) secondary (e.g., Internet searches) and primary (e.g., experiments &/or studies) research and use their findings for negotiating with peers personal and/or social actions they implement to address harms of interest to them. Such 'RiNA' (research-informed and negotiated action) projects would be *student-directed* and *open-ended* (with multiple possible conclusions). Since many students lack expertise, confidence and motivation for such autonomous projects, however, the STEPWISE framework urges teachers to provide students with one or more series of pedagogical lessons and student activities to help them eventually design and carry out their own RiNA projects. Some main principles for using this framework are given below.

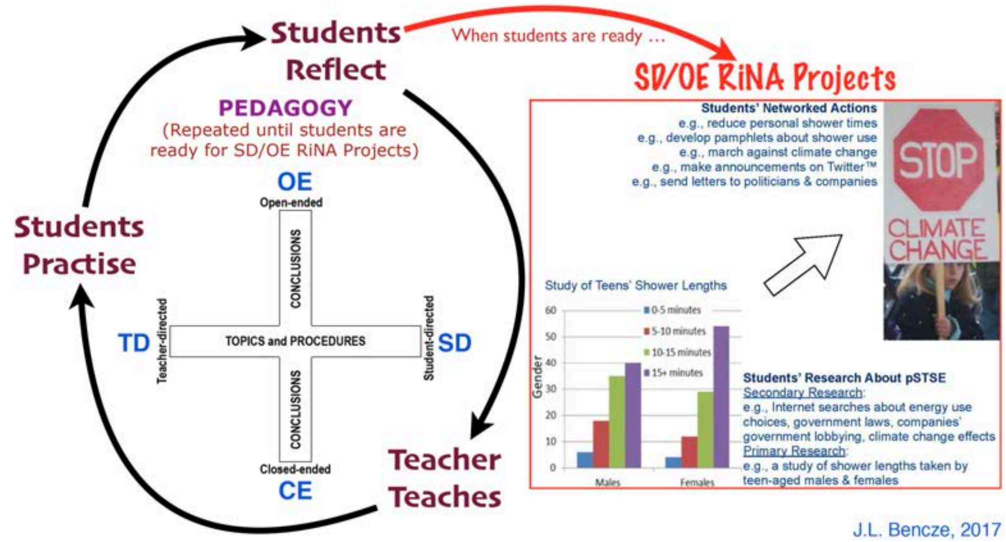

Figure 2: STEPWISE Pedagogical Framework.

Instead of first teaching students about ST(EM)SE relationships and RiNA projects other people have developed and implemented, the STEPWISE pedagogy begins ("Students Reflect") by encouraging students to reflect on their existing attitudes, skills, knowledge, etc. ('ASK') and 'express' them in different forms. It has been helpful, for example, to first show them various products of STEM fields, such as: hamburgers and French fries, cell phones, drugs, clothing fashions, cosmetics, weapons, etc. Students can say or write about what they like and dislike about these, and name people and groups who may like (e.g., companies & advertisers) and dislike (e.g., citizen activists, some government representatives) such products. Often, students' responses to such activities vary considerably - often because of differences in their experiences (e.g., culturally) and basic abilities (e.g., knowledge related to their families' wealth). To ensure all students have equal access to such ASK, therefore, the pedagogy next ("Teacher Teaches") recommends that the teacher provide more teacher-directed and closed-ended (with one or more pre-specified conclusions) lessons and activities to teach about important ST(EM)SE knowledge, relationships and RiNA projects by others. The teacher may use the schema in Figure 1, for example, to teach students about how governments often allow food companies to add sugars/sweeteners, salts, fats, chemical colourings, flavours and preservatives to foods and that research suggests such additives are linked to human illnesses, like heart disease, diabetes and cancer. The teacher also could show them a video that describes how other students researched food industry problems and developed and carried-out a campaign to educate citizens about possible harms from manufactured foods. We suggest such teaching should mainly be led by the teacher, mainly because some students may struggle with discovering such ASK through their own inquiries due to above-mentioned problems like family poverty and cultural and language differences.

Although the teacher has worked to ensure students know and understand certain ST(EM)SE relationships and people's RiNA projects to address harms they perceive about them, there is much logic and experiences to suggest that students then need to have more control over such projects to deepen their ASK about them. So, the third phase of the pedagogy ("Students' Practise") involves asking students design and implement RiNA projects to address harms of interest to them in particular ST(EM)SE relationships - with teacher assistance, as needed.

After one cycle through the STEPWISE pedagogy in Figure 2, the teacher may decide students are ready to self-direct ("SD/OE") RiNA projects. This may be the situation for some advantaged students. For many of them, however, especially if they have not conducted many such projects, a second (or third) set of teacher-supported lessons and activities will help - although it also is common for teachers to need to provide less and less support as students engage in more such projects.

STUDENT-LED RiNA PROJECTS

Once the teacher believes that most (if not all) the students have expertise, confidence and motivation to self-direct RiNA projects to address harms they perceive in ST(EM)SE relationships, the teacher should then ask students to develop, conduct and report on such projects. Typically, this means that the teacher will provide students with a formal assignment - often with a broad description of projects, deadlines for smaller parts of them (e.g., topics, methods, results, actions, etc.) and evaluation. As shown in Figure 2, for example, one group of students may carry out secondary (e.g., Internet searches) and primary (e.g., a study of students' shower lengths) research and, based on findings, negotiate with peers different actions - such as posters, pamphlets, videos and one or more marches.

BENEFITS OF STEPWISE PEDAGOGY AND RiNA PROJECTS

Preamble. The framework in Figure 2 (or variations of it) has enabled many students to develop and implement interesting and effective RiNA projects. Evidence of this claim is provided in different publications, including in an issue of the journal JASTE (goo.gl/N00b3s) edited by a teacher and featuring RiNA reports written by students and an edited book (goo.gl/q98JRv) featuring teachers' reports of their pedagogy and student projects and academics' analyses of STEPWISE frameworks. In doing so, it is apparent that students 'achieve' many learning outcomes, such as in terms of those for science curricula in the Canadian province of Ontario (goo.gl/Y73QL9). As indicated in Figure 3, this involves learning in three (somewhat overlapping) domains: *STSE Education* (e.g., ST(EM)SE relationships); *Skills Education* (e.g., study, experiment and social action designs); and, *Products Education* (e.g., knowledge produced by chemists, etc., such as chemistry of fats and 'trans-fats'). With such expertise, moreover, it seems that students' RiNA projects have led to some improvements in wellbeing of other individuals, societies and environments - such as appeared to be the case when students encouraged their school's administrators to fix school water fountains and allow them to post signs at them that encouraged students and teachers to use them instead of water in plastic bottles (which their research had determined contains toxins and cost much more than tap water). Research into educators' uses of the STEPWISE framework since its inception in 2006 suggest that many factors contribute to its successes.

Figure 3: Ontario Science Curriculum Goals.

Balancing Teacher and Student Learning Control. Much of the success of the STEPWISE framework appears to arise from its uses of various positions on the 'control-of-learning' schema shown in the middle of the pedagogical cycle in Figure 2. For instance, as described above, to ensure students come to know about and understand important ASK about ST(EM)SE relationships (more information about which is given below), teachers should use more direct (teacher-directed & closed-ended) instructional techniques (like 'telling,' 'showing' [e.g., videos] and 'demonstrating'). However, to personalize education for students and to motivate them to act to address harms, it seems clear that students need many opportunities (e.g., Students Reflect & Students Practise) to make decisions about various aspects of knowledge production and uses.

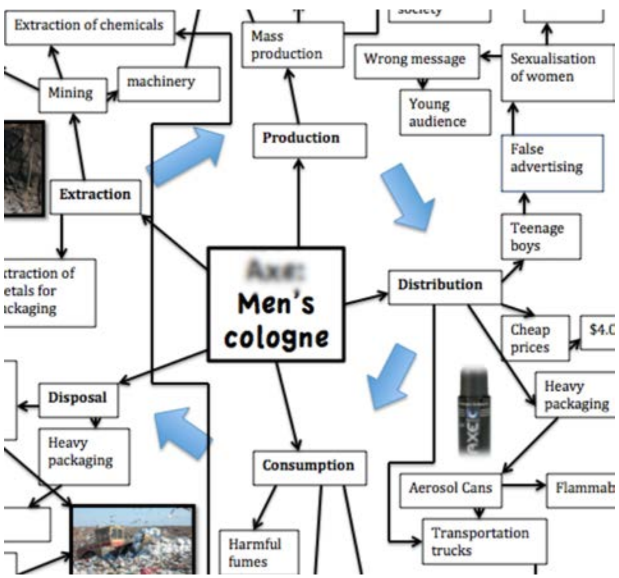

Figure 4: Students' Actor-Network Map.

Important Aspects of ST(EM)SE Relationships and RiNA Projects to Teach. At the very least, teachers should ensure that all students understand, as shown in Figure 1, that scientists do not work alone, but in relationships with technologists, engineers, mathematicians and, moreover, that their work often is greatly influenced by other people in society - including powerful people and groups, such as financiers and transnational corporations. At the same time, they should learn about specific cases of such influences on STEM fields being linked to harms to individuals, societies and/or environments - and examples of others' actions to address harms. To assist with such critical ST(EM)SE education, students should be taught about *actor-network theory* (ANT) - which conceives of things as part of networks of living, non-living & symbolic 'actants' - and how to elaborate ST(EM)SE relationships through it. Students can, for example, learn about collections of actants that cooperate (more or less) to support common purposes (e.g., 'prestige'). As indicated in Figure 4, for example, students mapped actants linked to a cologne. With such learning, students then can organize collections of actants (e.g., video & YouTube™) that support their causes. They also can, for example, develop technologies/innovations that function well, but also value social justice and environmental sustainability.

To teach about the nature of RiNA projects, the schema in Figure 5 may help teachers. This suggests that students' research ('science') into the 'World' may lead them to develop various 'Signs' (e.g., drawings, graphs, etc.) depicting their conceptions of ST(EM)SE relationships. After thought and negotiation, though, they may develop new Signs (e.g., a more sustainable cologne) and encourage people to use them (actions) in hopes of seeing new ST(EM)SE relationships develop. In translations between World and Sign, though, students could learn about *ideological* gaps, for instance - such as when advertisers *purposely* make Signs (advertisements) that idealize products (World).

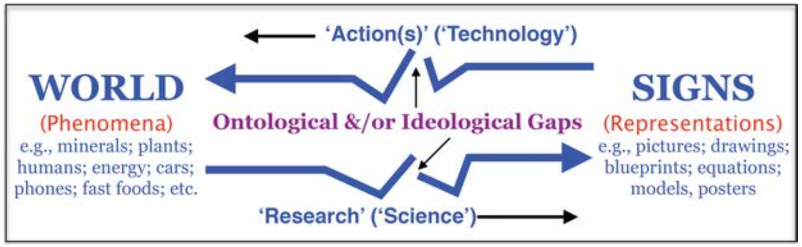

Figure 5: RiNA Project Analyses.

Although learning from secondary research (from others [e.g., teacher, Internet]) is very important, students often gain deeper understanding and attachments to relationships, harms and actions through 'primary' (first-hand) research. Although experimentation (purposely changing independent variables) can be effective in learning about ST(EM)SE relationships, conducting *correlational studies* (comparing naturally-changing variables) often are better - in cases, for example, where experiments may harm living things (e.g., tests of cigarettes). Also, students often benefit from *local* social studies, which can provide more information (including qualitative info. about friends and family) that can motivate local (and global) actions (e.g., less use of energy drinks [e.g., Red Bull™]).

Finally, although there is much teachers can teach about ST(EM)SE and RiNA, students also should reflect on the nature of their earlier RiNA projects and, through discussion and further thought, use some ideas (e.g., studies often are easier than experiments) to improve new RiNA projects.

CONTEXTS FOR STEPWISE IMPLEMENTATION

Although many of the points above can help students learn about ST(EM)SE relationships and to conduct RiNA projects, such outcomes also often depend on factors like: curricular support for them; the teacher's understanding/beliefs about the nature of science & technology; support from colleagues, administrators and parents; and, the teacher's expertise, confidence & motivation for such education. [To learn more about STEPWISE and access relevant resources, visit: www.stepwiser.ca]