There is broad agreement in the science education community that generating scientifically literate students is not only a good thing, but the main goal for science education. However, this begs the question of what does scientific literacy encompass? And what can science teachers do to strengthen students’ literacy? To explore these questions this paper aims to clarify the concept of scientific literacy and the philosophical principles that underlie it. Based on this information, strategies will be presented that can help to bring scientific literacy into the heart of everyday classroom activities.

Contemporary understandings of scientific literacy

While the term scientific literacy has come to have nuanced meanings, it predominantly holds the same agreed meaning as it did in when the National Research Council (1996) published the (American) National Science Education Standards. These standards stated, “Scientific literacy is the knowledge and understanding of scientific concepts and processes required for personal decision making, participation in civic and cultural affairs, and economic productivity” (p.22). DeBoer (2000) and others over the years have extended this discussion to emphasise where and how to use scientific terminology, to pose and evaluate arguments based on scientific evidence and apply appropriate conclusions, to understand and develop abilities to engage with ways of working scientifically, such as investigations, evaluating evidence, identifying patterns and thinking scientifically. But in the end, the common assumption is that scientific literacy implies an emphasis on scientific concepts, ideas and skills.

A number of critiques have questioned the emphasis on conceptual understanding. The major critiques, in the field of education, against this common assumption of scientific literacy are:

- Conceptual knowledge and conventional scientific processes are foregrounded attributes in scientific literacy at the expense of skills such as reasoning and communication skills and exploring more socially and, I would add, environmentally, responsible science (AAAS, 1998; Eisenhart, Finkel, and Marion, 1996).

- If conceptual knowledge is key, then who decides what type of knowledge the general public should have in relation to the vast breath of scientific knowledge. (Hodson, 1999).

- Being scientific literate needs to be situated within a collective experience, rather than being thought of as an individual attribute. A student who is simply a ‘receptor’ of science facts’ and is able to read, write and talk science is not necessarily scientifically literate, as they must also understand the fundamental conceptual, epistemic and social dimensions associated with the
scientific community – they must appreciate the collective view of what it means to do science, of how to think, communicate and argue in the beliefs and language of science. (Roth & Lee, 2003).

These holistic understandings of scientific literacy imply a more genuine and authentic interactivity with the knowledge base within which science is situated. It highlights that school science is more than just improving student’s science concept knowledge and skills, as it seeks to review science itself while also placing the science the students are exploring within the economic, sociocultural, religious, ecological, ideological, political and temporal environment of their local, national and international communities. This broader focus encourages student to have mastery of science concepts, and be able to make well thought through choices based on well-researched information, and develop skills that promote engaged citizenship within their democratic societies. To achieve this, teachers need to help students become responsible citizens able to think critically and creatively, analyse information, and more accurately appraise the associations and impacts of the countless choices and actions they make.

The above framing for scientific literacy suggests all three strands of the Australian Curriculum (Science) are needed to achieve this end. However, the agenda of becoming a responsible citizen resonates with the Science as a Human Endeavour strand. The compulsory inclusion of Science as a Human Endeavour as a strand unto itself is a bold move for science education in Australia. A move reflective of this generation of students who are less tolerant of issues presented outside their relevant contexts and more demanding to see a bigger picture of how and why science is useful to them. Many of these students have been using digital games, digital learning activities and social networking sites for most of their young lives. Through the Internet they have immediate access to a vast variety of perspectives and are connected to a wider community and its issues in ways that previous generations have not been. From an education perspective and to advance scientific literacy, these students need the skills, strategies and mindset to efficiently analyse all of the information that is available to them.

**What is Science as a Human Endeavour?**

Science as a Human Endeavour should not be defined by a single description but rather viewed as a movement in science education that is connected by the principle that science education is equally about people and culture as it is about science content and skills. This movement is not fixed but continually changes and grows. As science does not exist outside the context of society, the foundations that underpin this movement emphasise personal relationships to science within wider contexts and histories, and promotes active and transformative learning. Specifically, it promotes a reflection of science by placing knowledge within sociocultural frames for the purpose of developing better decision-makers. It aims to contribute to student’s abilities to be critical and creative thinkers, to establish ethical principals, to build language and negotiation skills, and to develop strategies and skills that will shape students thinking and understanding of science in lasting and personal ways. It responds to the call for science to be grounded in the lived experiences of the students while also connecting to the sociocultural environment of the community.
As Science as a Human Endeavour speaks to the interactive aspects of how science and society relate and influence daily lives, it doesn’t just necessitate that we change our teaching practices: it’s forcing us to rethink the teaching and learning of science and the reason why we are doing it. It involves viewing science education differently; and ensures that educators bring a variety of philosophies and perspectives into their teaching and learning of science. Making this transition will mean envisioning science’s deep connection to people, nature and culture. It means understanding that teaching science implies that science itself needs to be reflected on, and even critiqued. It means placing the discipline of science within socio-cultural frames and allowing students to view the current and historical nature of science. In this sense, Science as a Human Endeavour endorses 3 agendas: students generating a conceptually accurate understanding of the science concept being taught (via constructivist methods); students developing the ability to reflect on the nature of that science (Nature of Science: the philosophies, agenda, history and practices of science itself); and thirdly, for students to place all of this information within a wider socio-cultural framing.

The above agendas represent an underlying philosophy for Science as a Human Endeavour, however the lived experience of it can be, and has been, conceptualised many specific ways. These differences can be linked to diverse understandings of the purpose of science education, i.e., what should be taught, in what way, and for what purpose. This generic debate about the purpose of education is long standing and dates back to the Greeks, but has direct implications for contemporary science education.

...And what is its purpose?

The relationship between the purpose of science education, what knowledge is taught and what knowledge or skills are valued speaks to the realities of how privilege, power and knowledge are negotiated within science classrooms. Capitalism and social/environmental justice agendas compete for airtime and teachers are consciously and unconsciously asked to choose sides. However, in contemporary science education, the decks may be stacked towards capitalism. This is due to the current dominant vocational/neo-classical agenda of education. To make sense of this bias, I will use Fien’s (1993) suggestion that there are three distinct ‘ideological orientations’ in education.

The first and most prevalent orientation is the vocational/neo-classical orientation. This orientation underlines “the school’s role in maintaining, reproducing and legitimating social, economic and political structures and divisions by preparing students to compete successfully for job opportunities” (p.19). To investigate this orientation within contemporary science education in Australia we can simply look to Australia’s Chief Scientist position paper about STEM (Science, Technology, Engineering and Mathematics) education released at the start of August 2013. This report stated:

Australia’s productivity and competitiveness is under immense pressure. A key way to meet the emerging challenge of developing an economy for the 21st century is to grow our national skills base particularly the Science, Technology, Engineering and Mathematics (STEM) skills of our school leavers. Our relative decline of STEM skills is holding back our national
economy and causing real frustration for employers (Office of the Chief Scientist, 2013, p. 10).

The underlying agenda for science education in this framing equates to progress, namely economic progress (Calabrese Barton, 2001). And questions of what is taught in a science classroom, how and for what purpose highlight that science and technological knowledge, like all knowledge, is not objective, universal and fixed, but located historically within dominant philosophies. As a result, knowledge and knowledge production are always part of a larger network of power relations that become the site of conflict over what social knowledge should be established and to what end. This can be seen in the Australian Curriculum (Science) where Science as a Human Endeavour consists of patterns relating to:

- Advances in science and emerging sciences and technologies can significantly affect people’s lives, including generating new career opportunities
- Science understanding influences the development of practices in areas of human activity such as industry, agriculture and marine and terrestrial resource management
- People use understanding and skills from across the disciplines of science in their occupations
- Scientific understandings, discoveries and inventions are used to solve problems that directly affect peoples’ lives
- Science and technology contribute to finding solutions to a range of contemporary issues; these solutions may impact on other areas of society and involve ethical considerations

(ACARA, n.d.)

The second way of making sense of the purpose for science education relates to the liberal/progressive ideology. Fien’s (1993) explains that this orientation is said to “prepare students for socially responsible use of their talents and attainments” (p.19). Progressivism is based upon the notion that each individual has uniquely creative potentialities, and that schools in which students are encouraged to develop these potentialities are the best guarantee of society’s devotion to human worth and social change (Dewey, 1993). Dewey’s basic educational aim was for the generation of more creative intelligence in working towards a world of peace, freedom and opportunities. Education’s duty in this orientation is a moral one where there is an adjustment of the individual’s activities on the basis of social consciousness. This generates social reconstruction (Dewey, 1993). The goal is to educate the students so they have full and ready use of their capabilities within the society (Dewey, 1993).

This orientation can be seen in the Australian Curriculum (Science) where Science as a Human Endeavour consists of patterns relating to:

- People use science in their daily lives, including when caring for their environment and living things
- Science knowledge helps people to understand the effect of their actions
- Important contributions to the advancement of science have been made by people from a range of cultures
- Scientific understandings, discoveries and inventions are used to solve problems that directly affect peoples’ lives
- Scientific knowledge is used to inform personal and community decisions
• People can use scientific knowledge to evaluate whether they should accept claims, explanations or predictions (ACARA, n.d.)

The last of educational orientation is the socially critical ideology. The term *critical* as it is used here does not mean finding faults or negative thinking, but rather thinking that evaluates and critiques assumptions, thoughts, reasons and actions. This critique encourages the differentiation between poor and strong reasoning, and encourages people to evaluate conclusions in light of the best and most complete evidence. It is a skill set that needs to be modeled, taught and repeatedly practiced, just as any other valued skill set would be. As such, this orientation envisages school and society in a dialectic relationship where each informs the others action “with a stress on socially, morally, and politically justifiable conflict resolutions” (Fien, 1993, p.19). Both progressivism and socially critical ideology call for institutions, principles and methods to channel and master the changing nature of society into humane ends and greater participant inclusion. Fundamentally, progressivism and socially critical ideology also share a belief in the intrinsic value of educational activities. Students should learn by living the experience rather than having it ready-made or imposed upon them. Another commonality is the belief in a cross-curricular perspective on schooling. Progressivism and socially critical ideology maintain that it is not essential to rid the schools of separate subject matter, but it is fundamentally important to emphasise the cross-curricular nature of experiences that the students engage in. Progressive and socially critical pedagogues agree that education should be transformative, but progressivists do not take into account that human growth and emancipation are dependent upon political emancipation. The fundamental distinction here is that socially critical education maintains schools have the potential to transform society, while the other two orientations use schools for social reproduction (Fien, 1995). The tension between formal education being used for social transformation or social reproduction emphasises that schools are not neutral institutions. Schools have political agendas. They:

encourage or do not encourage persons to develop and use their critical capacities to examine the prevailing political, social and cultural arrangements and the part their own acts...play in sustaining or changing these arrangements.

(Berlak & Berlak, 1981, p. 253)

In science education the intent of socially critical education is to acknowledgement and critique the role science plays in advancing industrialisation, digitalisation, national economic agendas and the resulting social and environmental degradation (Bencze, 2001). Bowers (2004) argues that science education should be associated with empowerment and emancipation rather than the industrial-driven market place. He further argues that within the dominant science curricula, “students will not learn about the role of science in reinforcing the deep cultural assumptions that lead to environmentally destructive ways of thinking and behaviors” (2004, p. 224).

Gruenewald, (2004) speaks to contemporary education agendas when he argues that despite the good intentions of some educators, the purpose of science education is still to prepare young people to compete in the global economy. This third orientation attempts to offer a counter, to disrupt this assumption and create a space for new possibilities. It involves a socio-political, economic and environmental reflection on science and science education. In this orientation, science education promotes awareness, understanding and collaborative action about the injustices associated with
issues they are learning about in science classrooms. Students are encouraged to identify bias in what they learn through what is considered to be a thoughtful, ethically based, responsible and critical examination of social and environmental justice issues. It promotes social critique and [political] action in students, and offers the potential for changing current political, economic, social, cultural and ecological ideas and values.

**So what does progressive and/or socially critical pedagogy look like in practice?**

Understanding and practicing a progressive or socially critical form of Science as a Human Endeavour can be viewed as challenging since many of us who teach science have been taught through or with bias towards the vocational/neo-classical orientation. To more fully understand how each orientation can be viewed and enacted, I will explore a few practical examples.

A vocational/neo-classical agenda place a strong emphasis on a narrow mastery of conventional explanations and techniques of established science information. This has historically manifested as memorizing facts, definitions and diagrams etc. More likely in contemporary science education, rather than memorizing information, this can present as preparing students to solve a list of standard problems such as:

- What is climate change?
- How do people use science in their daily lives?
- Describe changes in [inset concept]?
- Present information about an Australian who has advanced science
- How has science contributed to finding solutions to [insert concept]?

While these kinds of questions might be of interest to school students, they do not constitute a powerful approach to teaching Science as a Human Endeavour. To more fully develop analytical and critical thinking skills, additional aspects are needed: skills such as understanding how scientists establish their scientific understandings within the framework of their intuitive thoughts and beliefs, and within wider social understandings. By coming to understand this, students may realise that science does not arise in a purely impersonal way (derived solely from experimentation). Science also involves human thought, logic, assumptions and intuition. In this way student can develop a sense that scientific understanding, although powerful, is also fallible.

Students can learn to be critical thinkers and consumers of the claims of science they see the social media that surrounds them. Through critique, students can develop the skills of independent thought, and can appreciate that at times, it is possible to come to an understanding of the world independent of authorities. By researching, analyzing and evaluating claims, students can appreciate that doing and understanding science is not just for *someone* else. This understanding is key within a progressive or socially critical orientation of Science as a Human Endeavour.

Exploring Science as a Human Endeavour with a progressive or socially critical frame involves engagement with analysing and evaluating reasons and evidence; making assumptions explicit and evaluating them; seeking out the most complete information, explanations and evidence; seeking to reconcile apparent contradictions; and distinguishing what is known from that is merely suspected to be true. This also involves seeking complexity of understanding from simple, concrete ideas to abstract ideas; moving from a limited knowledge of science to more in-depth and broader
knowledge of science and the world; applying scientific knowledge to contexts that are local and personal to those that are societal and global; being able to develop critical judgments that move from simple right or wrong assessments to complex evaluations that may or may not have clearly defined solutions; and finally, to moving from making decisions based on limited knowledge and made with teacher guidance, towards making decisions and presenting argumentation based on extensive research, involving personal judgment and made independently, without specific teacher guidance.

To illustrate this, I will provide an example of a teaching strategy that I have used from grade 4 to grade 12, and also in pre-service teacher classrooms.

**Step One:**
In relation to the science information the students are exploring in their unit, ask them to choose a concept, for example: water, air, climate change, electricity etc. Or this can be a more focused to a specific animal (maybe a socially controversial animal like a bat, shark, cane toad etc.), or the concept could be a plant or thing. The more specific the concept is, the easier it will be for the students to explore it within the framework below.

This concept can be the same concept for the class, or individuals can be asked to choose their own. How you enact this will only be limited by your imagination.

Let call this concept ‘C’ and let’s depict it as:

C

The first step is to ask the student to *explain* C in as much detail as they can. They can do this in any way that you, as the teacher, would like. For example they can write information without using any reference material, just their own knowledge to date, or they could use their notes from their science notebook, or from their notes and other references, etc.

To help guide students’ understanding of the different steps, I offer a series of questions under each step. However, once the students understand the purpose of each step within the framework, they will be able to generate their own questions that relate more suitably to their specific concept. Learning and practicing the development of their own questions becomes part of this valuable skills set.

To deeply explore the students’ understanding of the concept itself, the following questions may act as a guide:

- What assumptions or beliefs did you, and do you, have about C?
- What have you learnt about C from school – and by what methods?
- What intuitions do you have about C?
- Ask your peers what they know about C (ask the students to write this information in another colour so they get used to the idea of acknowledging work that is not their own)
- What do you believe your teacher thinks about C – and why do you think this?
- What do you believe you family thinks about C – and why do you think this?
Step Two:
Students are then asked to place this information in relation to their own life and their own local setting. Again, once the students understand this task, they will be able to generate questions better suited to their concept. The following question can be of help to guide students, depending on the concept or thing chosen.

- How does C specifically relate to:
  - Your life?
  - Your family’s life?
  - Your social life?
- What do you think your local community thinks about C – and why do you think this?
- Are their different understandings or issues within your local community associated with C?
- What are all the ways people use or engage with C?
- Do people buy C?
- Can you directly see, feel, taste or smell C?
- Why does it look, feel, taste or smell the way it does?
- Are there any alternatives to C?
- What are the social (human) and environmental consequences of having or not having C?
- How does C get made?
- Does C get sold or delivered?
- What resources are used to make or use C?
- What by-products are produced by C directly or in the manufacturing of C?
- Under what conditions is C made?
- If there are any profits from making, selling or delivering C, then where and to whom do they go?

Step Three:
Students are then asked to place this information within a state/territory, national and global frame. Again the questions will help to guide students with this process.

- What do you think your national and global community thinks about C – and why do you think this?
- Are there different understandings or issues within your national and global community associated with C? Why do you think these exist?
- Does C exist in other places (different states, territories, or countries)?
- What do other places do with or without C?
- Does our own engagement or use of C affect life elsewhere on the planet?
- Is C made or built elsewhere?
- Are building materials from other places used in the production of C?
- If it is built: do other countries send their raw materials elsewhere to build C – and why?
- Who organises this kind of system?
Step Four:
The past two steps have asked students to understand C within the local, national and global space. Step four begins a series of steps that asks students to explore C within a temporal dimension. This step specifically looks at the student’s recent engagement with C.

- How has C been involved in your life recently?
- When do you think that particular C came from, was born or made?
- Does C change over time as you use it?
- What determines how long you can engage with, or use C for?
- What social and/or environmental changes have affected C in the past few days, weeks or years and in what ways?
- What social and/or environmental changes will affect C in the next few days, weeks or years and in what ways?

Step Five:
This step asks students to relate C to a long-range time span.

- When did C first enter human history?
- What did C replace?
- How did C come into being and what was its original purpose?
- Why did C appear when it did?
- How has C changed over time?
- Why has C changed over time?
- What will C look like in ten or twenty years from now?

Step Six: Action dimension
This step asks students to explore what they could actually do to enact change.

- Do you have any alternative ideas for how C should be and why?
- What changes are needed in C?
- What can you do to help C move towards this vision?
• What organisations, government policies or social agendas/understandings are inhibiting moving towards this vision?
• What organisations, government policies or social agendas/understandings are supporting this vision?
• Who or what organisations could you contact and express your concerns, or your support, for the way they are helping or inhibiting this vision?
• What organisations support this vision? And what could you do to support them?
• What social media mechanisms could you become involved with to help support this vision?
• What are the consequences of doing nothing?

**Conclusion**

Scientific literacy includes ensuring students place both their understandings of science and the ways of working and thinking in science into a sociocultural context. As such, Science as a Human Endeavour is as critical to scientific literacy as understanding scientific concepts and learning scientific skills. But Science as a Human Endeavour has many orientations, and how it is valued and enacted can determine the degree to which students are given the opportunity to fully develop analytical and critical thinking skills. To promote deeper engagement, this paper provided both theory and a suggested practice for the progressive and/or socially critical orientation towards Science as a Human Endeavour.

**References**


