GLOBAL CCS INSTITUTE

CCS EDUCATION IN DEVELOPING COUNTRIES: A GLOBAL CCS INSTITUTE GUIDANCE PAPER

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It is hoped that this guidance paper can help shape the work of CCS stakeholder engagement practitioners and researchers around the world in order to continue the excellent work being done to engage, inform, and educate stakeholders globally.

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"Many earth-related environmental challenges facing our evolving world can only be addressed if young generations are equipped with necessary knowledge, and this starts at an early age through education." UNESCO

Introduction

Education is considered an important component of carbon capture and storage (CCS) outreach programs. Educational resources are often perceived as a community benefit (Ashworth et al., 2012). Schools may provide a focal point for engaging in stakeholder support and capacity building, as well as raising awareness and understanding of local CCS activities. However, developing relevant CCS educational materials can be challenging. Considerations such as educational standards, language, and conceptual fit with existing curriculum, teacher capacity, and placing CCS in a meaningful context, all contribute to the implementation of CCS-related curriculum in all countries. Developing countries may face additional challenges related to literacy rates, socio-economic factors, language and equity barriers, school infrastructure, and financial resources. Furthermore, education systems and learning styles vary considerably across the globe making direct translation of educational curriculum problematic.

Experience shows that in order for CCS education to be effective, it must take place within a greater context of energy and/or climate change education. Educators in both developed and developing countries have many subjects and little time to teach very specific content, such as CCS. However, within the context of science, climate studies, and sustainable low carbon energy, CCS can be effectively integrated to demonstrate concepts such as the relationship between science and society.

Creation and translation of educational materials is, however, just one component of quality educational programs. Education initiatives are most often successful if materials are adapted to be specific to the context in which they will be used, teachers are involved and supported in the creation of materials, teachers work with experts to adapt materials and create related activities, and teachers train each other in the use and implementation of curricula (Greenberg, 2013). Building capacity among teachers to use and teach adapted materials specific to each country's educational system is critical to the long-term implementation of content related to sustainable energy and CCS.

In support of these educational goals, the Global CCS Institute has supported a closer examination of CCS educational strategies, cultural and educational sensitivities for educational implementation, and educationally sound practices for the development of CCS education materials in developed and developing countries.

While it is critical to have comprehensive education and outreach in all countries, it is especially important that education and outreach in developing countries be adapted and suited to the specific needs of the country. This paper provides a review of existing education literature helpful to developing CCS education in developed and developing countries, discusses some of the opportunities and challenges of creating CCS education programs in developing nations in a case study of the educational efforts of the South African Centre for CCS (SACCCS), provides a comprehensive set of key findings and recommendations for those developing, or delivering, outreach and education initiatives for CCS or similar low carbon technologies, provides a collection of useful questions to help guide the development of any education program, and offers a wide variety of global educational resources.

Considerations for CCS education from the literature

The ability to address significant earth-related global environmental challenges can only be accomplished through education begun at an early age (UNESCO, 2012). However, in many countries, earth science education is lagging or relegated to lessor importance than other mathematics and science subjects. To further understand the needs of the next generation of earth scientists, UNESCO conducted a series of regional scoping workshops to assess regional capacity and needs throughout Africa. Their findings focus on key needs to ensure that education contributes to sound scientific problem solving and the ability for current and future citizens to meet the challenges and opportunities for sustainable development (UNESCO, 2012). These key findings include the need for:

- Enhancing multidisciplinary approaches in research and teaching of earth science
- Engaging in outreach directed at decision-makers and general public to demonstrate the importance of earth science as a key driver for sustainable development
- Including earth science in the school curriculum at primary and secondary levels
- Facilitating networks (new and old) for scientific research and global community
- Investing in improving analytical facilities, networks, and equipment
- Building strong connections between industry and universities

Carbon capture and storage education provides a unique opportunity to fulfil many of these objectives and to further connect science and mathematics with current events. However, CCS, as a subject, needs to contribute to a complex bigger educational picture in which existing standards, curriculums, and pressing needs compete for time and resources. Teachers are often juggling multiple priorities, certain subjects or concepts may be taught only at certain times, and educational needs and standards change frequently. It is important that CCS education programs seek to integrate and align with existing systems.

Additional programming or activities must be mapped on to existing educational requirements and/or integrated into the educational system in meaningful ways. Programs fall into two categories: 1) directly improve quantity or quality of instruction or 2) modify incentives for school personnel to do so (McKwan et al., 2015). Often an effective model is to combine instructional materials with well-aligned efforts to improve teacher capacity through professional development (McKwan et al., 2015).

In fact, the geosciences are a useful platform to study global climate change due to the global nature of phenomena being studied, as well as the multidisciplinary nature of Earth studies. However, the convergence of multiple disciplines can generate models that conflict and potentially result in scientific controversies (Dolphin and Dodick, 2014).

Model-based approach to climate change learning

Using a model-based approach to learning about global climate change can provide a platform for discussion of subjects such as geologic storage of CO_2 as a climate mitigation strategy. As an example, models might be used to have students identify fundamental concepts or 'big ideas' related to climate change (Dolphin and Dodick, 2014). Next students identify secondary concepts or disciplines important to the study of global climate change, such as geology, atmospheric science, and environmental science. Within each secondary concept, 3-4 tertiary subjects are identified, which allow students to focus on one manageable construct within the entire global climate change subject. Students then work to construct a mental model that addresses questions of the key scientific concepts within their focus area, conduct discussion and research into the nature of the subject, and formulate theories about causes. Students work in small groups to identify strengths and limitations of historical models as well as their own. Throughout the process, students are encouraged to explore controversies surrounding global climate change and their particular focus area.

Some scepticism exists, especially in the US, about the verity of climate change. While most climate scientists surveyed agree that climate change is occurring (Doran and Zimmerman, 2009; Oreske, 2004), the public perception or concern about global climate change can vary. This variability can impact student perceptions and understanding of how the atmosphere works. Students face two specific challenges: complexity and misperception/ preconceptions. Global climate change is a complex scientific problem requiring multi-disciplinary study by experts, including climate scientists, oceanographers, atmospheric scientists, geologists, economists, social scientists, and more (Dolphin and Dodick, 2014). This multi-disciplinary approach requires a broad background students have often not yet developed. Additionally, students may hold large numbers of misconceptions about climate change and atmospheric issues (Gautier et al., 2006; Jeffries et al., 2001; Shepardson et al., 2011, and Theisen, 2011). Students must also overcome misinformation about global climate change from vocal sceptics and politicians with anti-climate change agendas, who are often the source of the controversy (Theisen, 2011). Especially because students (and other members of the general public) often use the media as their primary source of information (Dupigny-Giroux, 2010).

However, utilising scientific controversies to teach geosciences allows for the detailed exploration of scientific case studies that may be impactful in four areas:

1. Present in popular media
2. Global impact, influence on all earth systems
3. Highlights history and philosophy of earth science
4. Use of complex variables to determine causation (Dolphin and Dodick, 2014).

Traditional and mainstream approaches to climate change

Bridging connections between Western concepts of climate change and traditional understanding of landscape is critical to developing greater understanding of the implications of climate change, as well as bringing students from traditional backgrounds to science, technology, engineering and maths (STEM) education (Reano and Ridgeway, 2015). For example, in the United States, few Native American students are drawn to pursue careers in STEM disciplines (Beede et al., 2011). Yet, these students come to learn that earth science is connected to the traditional knowledge shared by their ancestors. The study of climate change in educational programs for developing countries can likewise draw connections between Western science while serving to draw useful information from traditional sources, which serves to preserve cultural identities (Reano and Ridgeway, 2015). In fact, important links between culturally diverse communities and earth science can be nurtured by integrating them into educational programs. Specialists who develop programs or activities to teach climate change and carbon storage concepts to students and communities with limited Western knowledge should seek ways to ensure that their research specialties can be put into beneficial cultural terms (Reano and Ridgeway, 2015). This is especially true, as stated by Reano and Ridgeway (2015), because "while geologic concepts are universal, cultural concepts are [quite] specific (p. 26)."

Using place-based education (PBE) allows for accessibility to scientific concepts for people from varied backgrounds (Gruenewald, 2003; King, 2008; Semken and Brandt, 2010). PBE, as defined by Reano and Ridgeway (2015, p. 27) is:

> *…an education framework that can utilize landscapes/places as mediums through which cultural traditions and Western science inform each other through the lives of people as they experience these places.*

PBE builds on the Situated Learn work of Lave and Wegner (1991) in which knowledge is situated within the social context of a community, the tools and practices employed, and the activities undertaken. PBE provides a mechanism for combining scientific knowledge of climate change, with knowledge that exists within student's cultural frame (Barnhard and Kawagley, 2005). PBE can also provide scientists working in a region much needed historical information about natural phenomena such as carbon dioxide (CO_2) seeps and places where storage sites might encounter containment challenges.

This approach requires science instructors and informal educators to put science into a cultural perspective (Reano and Ridgeway, 2015). The advantage of this approach is that it leads to greater understanding on the educator or researcher's part of the cultural context in which they are operating. In this way respect for cultural knowledge and customs is built. In order to operate within this framework, it is important to gain respect for cultural boundaries, including gaining consent to use traditional knowledge for teaching purposes (Reano and Ridgeway, 2015). This should be done in close collaboration with Elders and governing entities of traditional communities. Key aspects of these relationships include allowing for the time necessary to build the relationship and trust between parties.

An excellent example of First National perspective education was undertaken by the Regina Catholic Schools in Regina, Saskatchewan, Canada. Lessons, interviews, and information specifically related to First Nation environmental perspectives of CCS, climate, and the landscape have students examine the relationship between resources, ecosystems, and natural balance (see Educational resource page).

A significant body of literature exists on educational frameworks such as Situated Learning and Place-based Education that can be drawn upon to support program or activity development that favours local understandings and seeks to draw connections between STEM disciplines and concepts, such as climate change, with traditional understandings and historical knowledge of landscape and climate over time.

Equity and education

The issue of educational equity is of importance to consider when developing an education strategy. The work of Gutierrez (2007) focuses on successful learning environments for students marginalised by society. Her work seeks to give voice to contextual factors that foster or inhibit learning. Equity in education, according to Guiterrez (2008), must be framed in dominant (Western thought) and critical (local knowledge/traditional) domains. Equity in education has four key dimensions: *Access, Achievement, Identity*, and *Power*.

- *Access* considers resources students have available and their "opportunity to learn." *Access* fails to address past injustices.
- *Achievement* relates to student outcomes and is measured in tangible results, such as standardised tests.
- *Identity* is the personal, cultural, and linguistic capacity to participate in the classroom. *Identity* considers the balance between self and the global community.
- *Power* addresses issues of social transformation, voice, and opportunities to use knowledge as an analytical tool to critique society.

The *Access* and *Achievement* axis comprises dominant (Western) knowledge and prepares the student to participate in society. Whereas *Identity* and *Power* make up the critical axis (local knowledge/traditional thought), where identity can be seen as a precursor to power. All four dimensions play a role in equity for students in education and can contribute to education strategies. Students can benefit from using live experiences to make sense of scientific problems (Gutierrez, 2008). In this way, traditional knowledge and ways of knowing are combined with scientific thought, thereby engaging local and national value systems.

Trust and CCS education context

L'Orange Seigo et al. (2014) provide an excellent meta-analysis of stakeholder engagement research undertaken through the time of publication. Their review is organised according to the acceptance framework defined by Huijts et al. (2012) which examines several factors related to public acceptance: acceptance/attitude, knowledge, experience, trust, fairness, affect, perceived costs, perceived risks, perceived benefits, outcome efficacy, and problem perception. Their findings suggest that trust is the most important predictor of acceptance and that trust can be enhanced through fair procedures, honest communications, and collaboration of stakeholder groups (L'Orange Seigo et al., 2014). Perceived benefits are the single best predictor for acceptance and are influenced by trust, which is especially important at the local level. Other important factors include fairness, perceived risks, and energy context.

Energy context is an indicator of the need for discussion of CCS in the broader context of alternatives. CCS is more positively viewed and considered in the context of other options rather than in isolation (L'Orange Seigo et al., 2014). Education context can be drawn from these findings to enhance learning. Areas of confusion surrounding CCS include:

- Role of CO_2 in the environment
    - Where it comes from, impacts on climate, human health
- Misconceptions around geologic storage and behaviour of CO_2 in the subsurface
- CCS in consideration with other options for climate change mitigation, who supports CCS and why, what are the costs and benefits of CCS

Other factors to consider include the historical and social context of host communities (DOE, 2009; Wade & Greenberg, 2011; L'Orange Seigo et al., 2014). CCS does not occur in isolation in the experience of the general public. CCS is understood through the context of a variety of experiences, which can be positive, neutral, or negative. Understanding previous stakeholder experiences influences the ability to build connections, enhance understanding, and create familiarity with elements of a project. Trust and fairness can play a role here as related to previous experience and for this reason, local collaborative partners in education and other programs, are essential to help understand the local context and identify local benefits (L'Orange Seigo et al., 2014).

Literature summary points

- Earth science is recognised as a subject of critical importance by UNESCO, and as a key driver for sustainable development.
- Additional education programming must be mapped on to existing educational requirements and/or integrated into the educational system in meaningful ways.
- A model-based approach can be a particularly useful method for teaching and learning about climate change as a complex, multidisciplinary issue.
- It is important to be aware of climate scepticism, but it is also possible to use this as a powerful teaching tool.
- Climate change education can serve as a bridge between traditional and Western knowledge sources bringing Elders and local experts together.
- Place-based education allows for accessibility to scientific concepts for people with varied backgrounds.
- Cultural boundaries need to be understood and respected, which should be done in close collaboration with Elders and governing entities in traditional communities.
- Equity in education has multiple components to be considered, including Access, Achievement, Identity, and Power.
- Trust is the most important predictor of stakeholder acceptance that can be enhanced through fair procedures, honest communications, and collaboration.
- It is important to consider the historical and social context of project host communities.

CCS education in practice: A South African example

The South African Government has committed the country to reduce CO_2 emissions by 42 per cent by in 2020. South Africa has a potential to implement CCS as part of a portfolio of CO_2 mitigation technologies to help address CO_2 emissions from large point sources, such as power plants and industrial facilities. Since 2004, a significant amount of work has been done, and will continue, to explore South Africa's potential to deploy CCS. South Africa is planning a Pilot CO_2 Storage Project (PCSP) provided suitable geological formations are found on-shore.

Stakeholder engagement is a critical component of the national and local approach to CCS in general and the South African PCSP specifically. The South African approach to CCS stakeholder engagement and education has been comprehensive. Stakeholder engagement is conducted through the South African Centre for CCS (SACCCS) by a dedicated four-person team. The SACCCS stakeholder engagement team utilises a combined national and local engagement plan created specifically for the South African context (World Bank, 2012).

South Africa faces unique stakeholder engagement and educational challenges in a country with 11 official languages spoken in nine provinces. The unemployment rate is 26 per cent, with only 41 per cent of working-age population employed. Significant disparity can exist between schools, where in some cases 79 per cent have no libraries, 85 per cent have no laboratories, 77 per cent are without computer centres, and 14 per cent have no electricity (Modiko, 2014).

Key stakeholders were consulted to determine perceptions for national and local stakeholder engagement (World Bank, 2012). The key requirements for local stakeholder engagement are summarised as follows:

- Balance the need to engage with communities as early as possible, with adequate preparation of comprehensive engagement plans prior to engagement.
- Incorporate views of community leaders in the Stakeholder Engagement (SE) Integrated Communications Actions Plans (ICAPs).
- Garner community perspectives and consult with stakeholders on provincial and local municipality level.
- Involve provincial government and understand how climate change issues resonate at a provincial level.
- Hold provincial workshops and involve the National Committee for Climate Change (NCCC) in local stakeholder engagement initiatives.
- Involve provincial "champions" to assist with the implementation of stakeholder engagement plans for CCS.
- Understand and involve the local community hierarchy and provide information to communities in local languages.
- Pro-actively assist with socio-economic development initiatives in local areas.
- Communities should benefit from the implementation of CCS in South Africa, through tangible benefits such as skills development and job creation (even low skilled jobs).
- Provide information to local communities in local languages.

SACCCS has embarked on a comprehensive public outreach program and provides an opportunity for stakeholders to raise concerns, issues, and make suggestions. They have adopted a proactive approach to addressing concerns and questions. During early stakeholder engagement activities, it was recommended to SACCCS that schools were central places of information sharing in communities and that the SACCCS SE outreach programs should consider engaging students, teachers, and parents through the schools. As a result of this input, the SACCCS SE team has undertaken a deliberate approach to determining the most productive way in which they can accomplish multiple goals through their educational stakeholder engagement:

- Educate the general public and students about CCS.
- Provide information and greater understanding for local communities that may be located near the intended pilot project.

Stakeholder engagement recommendations and perceptions can also be applied to educational goals and objectives. At the suggestion of stakeholders in the engagement process, SACCCS has developed an educational strategy that includes a Pilot School Project (PSP) to engage middle school children in climate change and sustainable energy education (Modiko, 2014). SACCCS recognises the need for developing an educational strategy that includes, but is not limited to understanding of:

- National and local CCS context
- National and local educational context
- Analogous industry educational approaches
- Opportunities, challenges, benefits, legacy issues, upliftment
- Educational strategy development
- Educational content and activities selection and assessment
- Capacity building for teachers
- Implementation experiences, challenges, and success

As alluded in this report, during the consultation process with stakeholders in the potential pilot study areas, a suggestion was made that schools should form an integral part of the stakeholder engagement activities. To further inform this strategy, SACCCS undertook desktop research to benchmark against schools in the countries that are already deploying CCS technology such as the UK, US and Australia. The outcome of this study is the creation of the PSP, which is designed to bring Climate Change and CCS to life through Mathematics, Science, and Technology (MST). The PSP is designed to improve understanding of CCS with the South African public and to use real life examples of cutting edge science and technology, to bring to life traditional subjects like Chemistry, Mathematics, Physics and Geography to aid learners in the process of choosing their future study options.

In early 2015, the South African educational context and SACCCS approach to educational SE was discussed in a series of meetings with SACCCS staff, national and local educational stakeholders, and local leadership councils. Early lessons and recommendations from these provincial visits are included in this report.

The SACCCS educational strategy development serves as an excellent example of program development and is outlined here. Initially, SACCCS SE staff conducted educational research to further understand the South African formal and informal educational systems in order to make recommendations to senior management and appropriate committees for the entire SE team to utilise when defining their educational strategy. SACCCS divided their research into two categories:

1. Organisations
2. The nine provinces

Research into organisations in each province with the potential to raise platforms and educate about CCS within the country was conducted. Once platforms were identified, SACCCS SE team looked for organisations to engage with respect to CCS and climate change.

The SACCCS SE team then started to develop their educational strategy and further understand ways that they could create links between CCS, education, and communities. Recognising that most people knew nothing about CCS, SACCCS sought to find contextual links between CCS and other subjects, such as climate change, already being taught in schools. Upon looking into how to engage with schools they learned that education programs need support first at the national level and then the provincial level.

Therefore, SACCCS started with the Department of Basic Education, and once they had national approval and buy-in for integrating the PSP, they could move to the provinces to regional offices of education. They also conducted a survey of other informal education science and information centres with a focus on where and how to find and engage learners which culminated in the compilation of a database.

During the early phase of the educational program SACCCS found that support must first be gained from the Department of National Basic Education in order to show Provincial Educational Offices that the SACCCS educational program is accepted and can fit within the national curriculum.

SACCCS found that environmental and climate change education is conducted throughout South Africa and determined this to be where CCS might fit in the curriculum. Furthermore, it was important for SACCCS to demonstrate to the national educational leadership that South African activities will be benchmarked around other countries, and considered within the country. To fulfil this need, South Africa was benchmarked against Australia, Canada, United Kingdom, and the United States.

Another part of the study focused on how to raise general awareness of CCS in Science Centres, as well as provincial and local education districts. Introductory and iterative meetings with several potential educational partners and stakeholders took place, including but not limited to:

- Department of Education.
- Mindset (broadcasting channel) – to raise CCS awareness.
- Sci-Bono Science Center – to share resources, develop models and activities to illustrate CCS concepts.
- ESKOM Expo – the Expo is designed to raise awareness of STEM subjects through competitions for grades 5-12. The Expo is comprised of 13 categories for learners to conduct science research, three of which must fit into three categories (climate change, energy, and environmental). Competitions commence at the regional level to ultimately select a national winner. Learners take on a science project and come up with an innovative research program.
- Sasol Techno X – the annual expo for learners with displays and workshops, motivated toward careers in STEM and medicine, companies exhibit, demonstrate their career offerings, focusing on learners in grades 7-12, university students, and general public.
- South African National Biodiversity Institute – an organisation responsible for exploring, revealing, celebrating and championing biodiversity for the benefit of all South Africans within the Department of Environmental Affairs.

SACCCS further sought to understand how to work with teachers to support professional development that is convenient and meaningful. Regional education specialists were queried with respect to methods for supporting teachers in integrating CCS educational material. In some cases, teacher development is difficult to maintain. The recommendation was made to look for links with maths and science, to improve performance of learners. It was pointed out that workshops for teachers have to be conducted at a time that fits within their timetable. For example, the SA National Biodiversity Institute (SANBI) facilitates Environmental Education programs for learners, university students, educators and community members. This is done to encourage the beneficiaries to take responsibility for their environment. Several engagements were held between the two organisations, to discuss partnership programs. An agreement was made with an endeavour to raise awareness of CCS. The added advantage of partnering with SANBI is that it busses teachers and learners to their education centre.

The final stage of the preliminary work for the PSP was to meet with Provincial School officials. During these meetings, SACCCS SE team introduced themselves, discussed goals, explained CCS briefly, and asked how best they could work together. SACCCS explained the PSP and informed provincial leaders that they have met with the Department of Basic Education's Curricular Director, who gave them approval to liaise directly with the Provincial Education Districts. At the time of these meetings, SACCCS was very early in the planning stages and seeking engagement with Provincial Districts to involve their schools in a pilot study. The SE team sought to chart a way forward and suggested starting with teachers. SACCCS was careful to convey that the PSP was not an extra program, but a complimentary program that can complement existing content. SACCCS pointed out that they are mindful that CCS is not in curriculum, but noted that climate change is taught at very young age at schools. SACCCS reiterated that their goals for the PSP include:

- Raising awareness
- Identifying schools to work with
- Fitting in with climate change work already being undertaken
- Demonstrating the importance of science and innovation to young people in South Africa

- Assisting learners and school communities understand CCS as one of the technologies to mitigate climate change
- Showcasing and encouraging innovation and creativity

The SE team also discussed several key points that support provincial educational goals and demonstrated how the CCS PSP connected with school district missions could improve performance in math, science and technology (MST), improve capacity of teachers, highlight MST careers, connect MST in schools with societal issues, and show the relevance of pursuing careers and further education in MST.

The discussions with Provincial Education Leadership provided insight into planning and process of implementing CCS education programs. The work presented here is from the initial planning stages of the SACCCS education program. Considerable work has been conducted since these preliminary visits in 2015 and more information can be learned by contacting the SACCCS Stakeholder Engagement team.

Summary Points

- The stakeholder engagement process in South Africa informed specific educational strategies at the national and local levels.
- Also seen in the South African example, is the importance of considering the role that schools play in local communities.
- Collaboration with schools is necessary to integrate CCS education in a fair and equitable manner.
- Creating a link between existing science and mathematics curriculum and CCS is essential.
- Benchmarking studies against existing materials and/or programs can be beneficial and allow for greater understanding of the unique challenges to educational systems and teacher needs.
- Consider formal and informal educational venues
- Industry, government, museums, and other organisations are potential educational partners.
- Be prepared to support teacher professional development and the provision of strong resources to school districts.

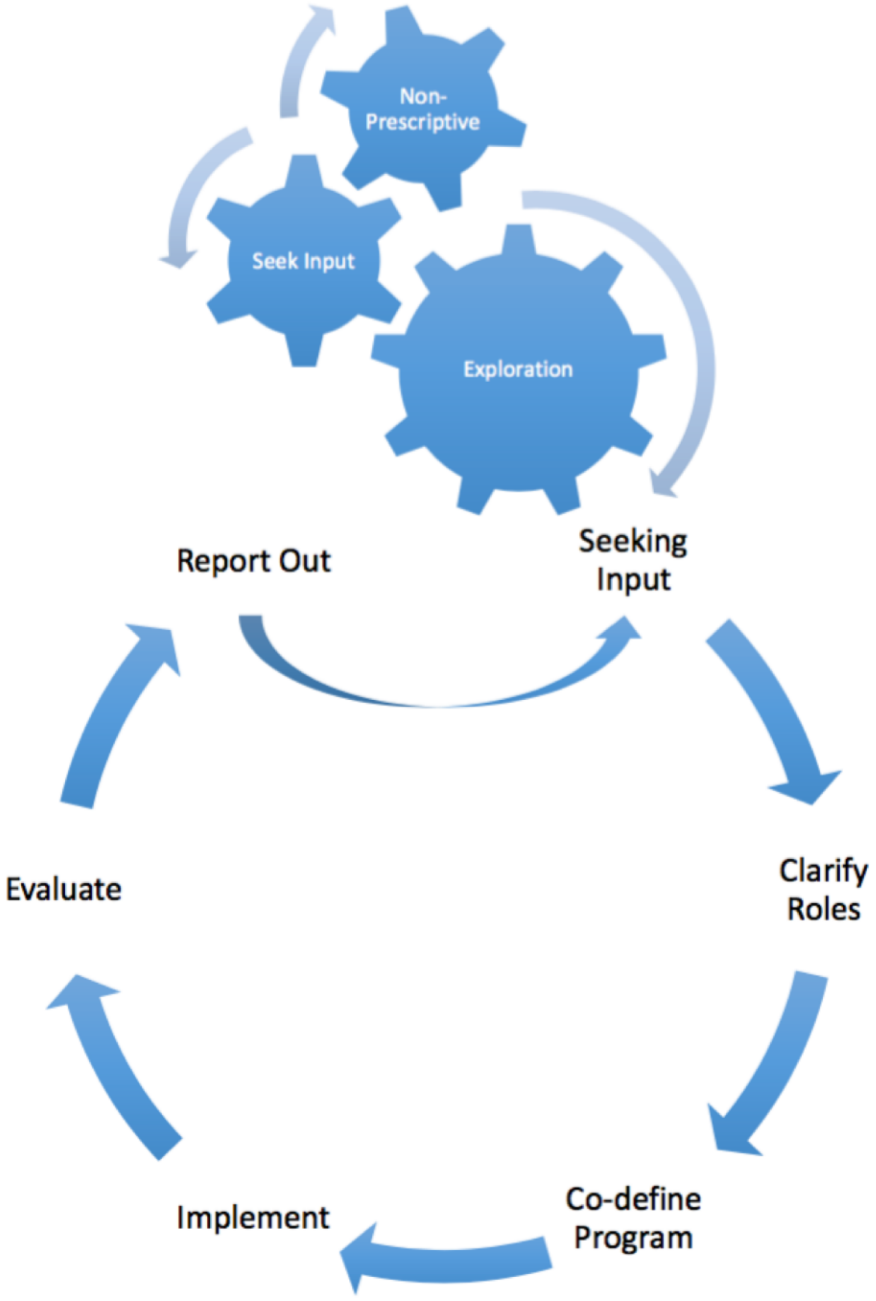
Key findings from the case study

The South African case study provides valuable experience in the integration of stakeholder engagement and educational objectives. Utilising the SACCCS methodology and approach, key findings are generalised below for use elsewhere. These key findings are for use by stakeholder engagement professionals, educators, project developers, and community leaders interested in integrating CCS into a broader educational curriculum. Furthermore, these findings can help guide the educational engagement process and facilitate the iterative processes need for a collaborative approach for those designing and developing CCS education programs within developed and developing countries.

Consultation and iterative processes are critical to success. National and local education systems and stakeholders are critical to understand prior to initial development of CCS education programs. Furthermore, it is critical to identify areas in which CCS can be mapped on to existing curricular content and goals.

Figure 1 shows a design approach which addresses how educational stakeholders can engage in the iterative process of mapping a CCS educational program onto existing content in the curriculum. This consultation-based education program development process begins with non-prescriptive ideas and goals for CCS education programs, seeks to get input from stakeholders, and explores connection possibilities, existing materials, and generates a concept paper for discussion. Concept discussions take place during which engagement with education stakeholders helps define and clarify roles for all groups, which then work together to co-define programs and coordinate implementation and training. Evaluation and assessment help define areas in which programs can improve and/or increase impacts. Results from program activities are shared with local, national, and international communities. The iterative process continues as required for further refinements.

Figure 1. Generalised method for educational stakeholder engagement process



Challenges can present major barriers and opportunities.

Working in a developing country can present challenges that require significant consideration and planning. Areas to give special consideration include:

- Meetings and Gatherings
  - Establishing stakeholder meetings, getting participants to meetings, and gaining access to key participants.
- CCS knowledge and learning curve
  - Requirement for extensive familiarisation/awareness raising activities with stakeholders often necessitates multiple meetings and exchanges of information.
  - It is important to build knowledge slowly to ensure you achieve the stakeholder's greatest understanding and comfort level.
  - After finding models and examples of educational materials these will likely need adaptation in order to be fit for purpose.

Collaboration to define timing, nature, and intent of CCS education programs is critical to success.

It is critical for CCS education programs to engage educational stakeholders to determine timing, program content and intent. Stakeholders must have involvement in defining how and when programs will be implemented. Figure 2 shows a generalised approach to introducing CCS education programs to key stakeholders based on the South African model. This approach ensures that key stakeholders at the local level are involved in the design and implementation of CCS education programs.

The approach allows for initial meetings in which program ideas are presented first in general terms, but later in more detailed discussions that include timing, materials, training, prerequisite content, curricular alignment, testing, support for teachers, coordination among teachers in multiple districts, and how to map onto existing programs.

Figure 2. Consultation-based Education Program Development Process.

Recommendations from literature and case study analysis

Conduct social site characterisation to generate deeper understanding and facilitate engagement potential. Significant benefits can be gained by conducting stakeholder analysis and social site characterisation studies to better understand national and local stakeholder views. Furthermore, leading a facilitated discussion with key educational stakeholders is important in order to determine and map educational goals.

Understand the national and regional education system. It is critical to understand how and when key scientific and mathematic concepts are taught. Consider how and when CCS aligns with key subjects, such as climate change, energy development, and global challenges. Further, it is important to understand curricular demands and existing teacher commitments. Consider when and where add-on programs can align or fulfil a role, such as afternoon programming.

Align national and local educational strategies to benefit from and mirror the national and local stakeholder engagement approach. Utilise existing stakeholder engagement plans and modify or adapt for specific education stakeholders. Work with education stakeholders to create education programs and strategy. It is important to understand who are the educational gatekeepers and entities that can facilitate introductions, processes, and procedures.

Place CCS in context and support education standards. CCS is part of climate change mitigation, energy, and sustainable future dialog. As such, CCS provides opportunity to use mathematics, science, and technology to examine real world problems. It is critical to align CCS with existing educational goals and subjects.

Engage experts to facilitate implementation and provide important programmatic recommendations. Go directly to the source. In many cases, the local and national education specialists offer insight into formal and informal avenues to align CCS education with national goals and objectives. Utilising this group of experts as a resource engages their expertise, defines a role for contribution, and allows for feedback, growth, and improvement.

Examine and understand legacy issues. A history of programming and external interaction will exist in any educational system. It is important to consider previous positive or negative experiences. Further, it is important to build trust and create long-term relationships that ensure that programs will continue to be supported.

Consider benefits for local school districts. One important area, in which CCS education programs can benefit school districts, is to make educational materials available (for example, through educational kits).

Partner with international CCS programs. Engage with organisations such as the Global CCS Institute to report back and present on using materials. Devise connection mechanisms for teachers and students to interact with international counterparts. Provide resources for teachers to ask questions, seek recommendations, and discuss challenges.

Ethical treatment of program participants is critical. Make sure that in conducting pilot studies or other programs that ethical practices are upheld. Consider ethics of one school getting benefits not given to other schools. Contact school districts and ethics governing body if conducting assessment.

Be prepared. Be prepared to answer and present on technical aspects of CCS and educational program details. It may be beneficial to develop a concept note at the national level to garner support, introduce concepts to partner organisations, and inform local educational stakeholders. Consider ahead of time contribution potential by key stakeholders, potential roles and responsibilities, and education specialist's contributions.

Ensure that professional development opportunities are convenient and meaningful for teachers. Achieving buy-in from teachers is critical for program success. Consider how integration of

education programs can impact teacher performance and classroom needs, and ensure that the program factors in any support mechanisms required for teachers. Key questions to ask are:

- Where are teachers starting from?
- What do they need to be successful?
- What does success look like for your organisation/for the school district?
- How can others support these shared goals?
- What do teachers and informal educators need in order to be confident implementing new programs and materials?

Use available resources. Many good CCS educational materials exist at present (see educational resources section). Utilising existing materials can help benchmark against other programs and provide expertise upon which to draw. It is important to recognise that differences may exist between educational systems and student achievement. Modification of activities may be necessary. Additionally, resources such as equipment and laboratories may be unavailable.

Use materials and activities that have been piloted previously. Using existing education materials that have been proven and tested in developed countries can save time and resources. Materials should be piloted in local schools and if modification is needed, undertaken with input from teachers, regional curriculum coaches, and other experts. The use of internationally developed materials may instill a sense of pride in learners because materials used elsewhere globally can make them feel on par with global peers. Materials which expose students to international perspectives, help build capacity and often link in with the original developers of the resources and establish links.

The credibility of resources greatly impacts teacher support. This can be enhanced if the professional development resources used during educator training, make use of internationally peer-reviewed and classroom tested materials.

Evaluate programs for impact and improvement. Formative evaluation of activities in the classroom can provide important feedback that helps in improving programs during development and implementation. Summative evaluation of programs can provide important support of program impacts. Evaluation or assessment teams should consider hiring observers from the local community to provide feedback to SACCCS and teachers and involve the community in lesson adaptation. This has the added benefit of providing employment to people in the area.

Conclusions

Schools in developed and developing countries are an important vehicle for stakeholder engagement. The opportunity to introduce CCS through contextual science and math, such as climate change, provides learning through doing and addressing real world issues. In order to proceed with educational programs, one must understand how national education systems work, what are the sources of informal education and how do they fit into formal education. It may be helpful to draft a concept note with a basic educational framework to facilitate discussions with Departments of Education and other groups.

Climate change education was a major theme at the COP21 in Paris. The international call to enhance climate change education, training, public awareness, public participation, and public access to information was a major theme. Three crucial actions highlighted by the UNESCO Director-General include integrating sustainable development more deeply into national education systems; giving teachers the knowledge needed to be successful; and creating stronger and more innovative partnerships. Furthermore, UNESCO sees education as the unifying thread between the 2030 Agenda for Sustainable Development and climate change action.

Education is a critical component to promoting lifestyle, behaviour, and attitude changes needed to advance sustainable development. More opportunities are needed for the development of CCS-related education segments and the integration of these activities into existing curriculum at national and local levels. The international community working together can facilitate supportive programs that bring educators together from around the world to enhance training, implementation, and educational opportunities. Through international collaboration, we can provide game changing sustainable development education that address global societal challenges, such as our changing climate.

Education resources

The list below provides a broad range of educational resources and information available at present. New materials continue to be developed globally and are available through the Global CCS Institute and other CCS projects and organisations. See Appendix A for the Global CCS Institute List of Educational Resources (2016).

Global CCS Institute:

http://co2degrees.com/learn-more/overview

https://www.youtube.com/channel/UCKXbwKL1MSTqKaFeGCvwvmA

https://twitter.com/co2degrees

https://www.facebook.com/co2degrees

https://www.globalccsinstitute.com/publications/carbon-capture-and-storage-educational-resources-evaluation-summary

First Nation Educational Resources:

http://rcsdcarboncapture.weebly.com/video-resources.html

http://rcsdcarboncapture.weebly.com/grade-7-resources.html (The first nation perspective lesson can be found as the first lesson in their Grade 7 resources)

https://www.globalccsinstitute.com/insights/authors/kirstyanderson/2013/11/29/regina-reveals-its-resources

Other Resources:

http://nsec.richland.edu

http://energy.gov/eere/education/education-homepage

http://www.need.org

http://www.netl.doe.gov/File%20Library/Research/Carbon-Storage/Project-Portfolio/BPM_PublicOutreach.pdf

http://www.cslforum.org/education/

http://www.sequestration.org/Step/index.html

http://www.iugscoge.com/index.html

http://www.unesco.org/new/en/natural-sciences/environment/earth-sciences/earth-science-education-in-africa/

http://www.unesco.org/new/fileadmin/MULTIMEDIA/HQ/SC/pdf/Earth_Science_Education_in_Africa-brochure_eng.pdf

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APPENDIX A – Global CCS Institute list of educational resources

Introduction to Carbon Capture and Storage (International)

Both Primary and secondary education resources with teacher notes. An inquiry based learning methodology, mapped to Australian Curriculum but successfully adapted internationally. Delivered to schools across Australia (with teacher PD) in conjunction with the Global CCS Institute as part of CSIRO's CarbonKids program (now known as Sustainable Future's program).

http://www.globalccsinstitute.com/publications/introduction-carbon-capture-and-storage

Reegle (International)

This website is a search engine for renewable energy and energy efficiency information. It includes energy context information and profiles for individual countries.

http://www.reegle.info/index.php

National Geographic Education (International)

This website includes teacher resources on the topics of energy and climate change, featuring videos and activities for all levels of schooling.

http://education.nationalgeographic.com/education/teaching-resources/?ar_a=1

UNESCO/UNEP (International)

Climate change in the classroom (2013)

A comprehensive online teacher resource with region specific information. Interactive online version with embedded links.

http://www.unesco.org/new/en/education/themes/leading-the-international-agenda/education-for-sustainable-development/climate-change-education/cce-clearinghouse/publications/

Climate change in the classroom (2011)

Full PDF version with more text outlining background of climate change topic.

http://unep.org/publications/contents/pub_details_search.asp?ID=6212

Education for sustainable development

Covers a range of issues including climate change, plus different teaching strategies

http://www.unesco.org/education/tlsf/index.html

Youth Xchange (International)

Wide range of information and activities focused on environmentally and socially responsible behaviours. Website has a global focus with guides available in multiple languages.

http://www.youthxchange.net/main/home.asp

PDF of 2011 guidebook:
http://www.unep.org/climatechange/Publications/Publication/tabid/429/language/en-US/Default.aspx?ID=6216

CarboSchools (Europe)

Provides brochures with background information on climate change science, activity examples and resources. Multiple languages and links to specific European country sites available.

http://www.carboeurope.org/education/libraryHome.php

Australian Science Teachers Association (ASTA) (Australia)

National Science Week 2012 teaching resource, “Energy Evolution”.

http://asta.edu.au/programs/natscienceweek/resources/resources2012

Oresome Resources (Australia)

Provides a range of resources related to energy technologies (and mining).

http://www.oresomeresources.com/

Clean Energy Council (Australia)

Series of factsheets about renewable energy technologies and energy efficiency.

http://www.cleanenergycouncil.org.au/resourcecentre/factsheets.html

CitiPower and Powercor (Australia)

Comprehensive list of factsheets for secondary school students.

http://www.citipower.com.au/Community_%26_Environment/Education/

Ergonia - Ergon Energy (Australia)

This website includes information on energy efficiency and energy technologies.

http://www.ergon.com.au/ergonia

Ausgrid (Australia)

Amy's Energy Save – interactive story with energy efficiency tips for young children

http://www.ausgrid.com.au/Common/Education.aspx

Australian Broadcasting Corporation (ABC) Splash (Australia)

Teacher and student resources, including a collection of materials on renewable energy.

http://splash.abc.net.au/media/-/m/36260/renewable-energy?source=search

http://splash.abc.net.au/res/collection/ae/

Green Cross Australia (Australia)

The Green Lane Diary website and resources includes chapters on energy and climate change science.

http://www.greenlanediary.org/diary-chapters.aspx

Future Sparks website contains, energy and climate related info, teacher resources, links etc.

http://futuresparks.org.au/

Australian Greenhouse Calculator (Australia)

Activities, animations, resources and information about climate change, energy sources and energy efficiency.

http://www.epa.vic.gov.au/AGC/teaching_ideas.html

Horizon Power (Australia)

Horizon Discovery Zone is an interactive computer based resource (PDF's of content can also be downloaded) that provides a tour through "Gilbert's House" to learn about electricity, generation and efficiency.

http://www.horizonpower.com.au/hdz/

Global education (Australia)

Teaching resources and information on global issues, with a global perspective. Sustainable energy sources is included as a topic.

http://www.globaleducation.edu.au/teaching-activity/sustainable-energy-sources-up.html

What to Do With CO_2? (United Kingdom)

UK curriculum mapped education resource from The Crown Estate and GeoBus.

The Crown Estate and GeoBus have designed this resource to provide teachers with an introduction to carbon capture and storage (CCS), a carbon emissions reduction technology. It provides

experiments, activities, lessons and homework ideas as well as links to a number of other useful CCS education resources. All the lessons have been linked to the UK curriculum codes (current at time of writing) this includes the Scottish Curriculum for excellence and the English Key Stage 3.

http://co2degrees.com/content/crown-estate-and-geobus-education-resources%20

E.ON Energy Experience (United Kingdom)

This website contains comprehensive teacher notes and activities for the classroom with links to UK curriculum. There are four units designed for different age groups, Energy Home, Energy Town, Energy Nation and Energy World. Each section is accompanied by interactive computer animations and activities.

http://www.eon-uk.com/EnergyExperience/default.htm

The Children's University of Manchester (United Kingdom)

Includes interactive computer-based activities on energy and climate change.

http://www.childrensuniversity.manchester.ac.uk/interactives/science/energy/

Energy Star Kids (United States)

Interactive website on energy and energy efficiency.

http://www.energystar.gov/index.cfm?c=kids.kids_index

National Energy Education Development (NEED) Project (United States)

Teaching guides and activities on energy for all ages, including in-depth background information on topics such as the history of energy and electricity.

http://www.need.org/

Energy Kids US Energy Information Administration (United States)

Comprehensive website with information, lesson plans and activities about energy.

http://www.eia.gov/kids/index.cfm

A student's guide to global climate change (United States – EPA)

Comprehensive website with information and computer-based activities about climate change science, impacts and solutions.

http://www.epa.gov/climatestudents/

National Aeronautics and Space Administration Climate Kids (United States)

Website contains information and mainly computer-based activities on climate change and energy technologies.

http://climatekids.nasa.gov/

California Energy Commission Energy Quest (United States)

Website includes information, classroom and computer-based activities on energy and energy technologies/sources.

http://www.energyquest.ca.gov/story/

ScienceNetLinks (United States)

Includes a collection of lesson plans and activities about the science of energy.

http://sciencenetlinks.com/collections/science-energy/

America's Home Energy Education Challenge (United States)

Includes lesson plans, activities about energy and energy efficiency for a range of age groups.

http://www.homeenergychallenge.org/Default.aspx

Siemens Foundation/Discovery Education (United States)

The "We Can Change the World Challenge" website features, ebooks, lesson plans, activities and resources about energy and climate.

http://www.wecanchange.com/

EnergyAustralia (Australia)

Useful diagrams in coal, gas, and wind power contained in factsheets, energy saving tip videos (Presented by CSIRO's Glenn Platt).

http://www.energyaustralia.com.au/about-us/media-centre/educational-resources

Act on CO2 (UK Government)

Carbon emission calculator for individuals and households.

http://carboncalculator.direct.gov.uk/index.html

SMARTGrid (US)

Information about the upgrading of the energy grid in the United States.

http://www.smartgrid.gov/the_smart_grid#smart_grid

Think Power (United Kingdom)

Kids section with interactive diagrams and game.

http://www.thinkpowersector.co.uk/power_kids/

CREATE (United Kingdom)

Teacher resources provided on the topic of energy.

http://www.create.org.uk/schools/teachers_resources.asp

Discovery Education (United States)

Various resources and lesson plans.

http://www.discoveryeducation.com/

Global Environmental and Outdoor Education Council (Canada)

Provides a list of links to a variety of Canadian-specific resources.

http://www.geoec.org/resources/index.html

My 2050 (United Kingdom)

School toolkit about emission targets.

https://www.gov.uk/government/publications/my2050-schools-toolkit

http://my2050.decc.gov.uk/

Resources for Rethinking (Canada)

Sustainability education resources.

http://www.r4r.ca/en

APPENDIX B – Useful questions for intiating education program design

Listed below are a series of questions that may prove beneficial to program developers, stakeholder engagement professionals, educators, and other interested parties when designing a CCS education program. This list is derived from experience of developing many programs (CCS-related or otherwise). The list is not meant to be exclusive, but is a good starting point. Questions can be divided into three groups:

1. Program Development Questions
2. Stakeholder Consideration Questions
3. Educational Implementation Questions

Program Development Questions:

- How much educational effort is needed?
- What type of education is needed (i.e., formal, informal, other)?
- Where do educational activities need to take place?
- How do you strike the balance between national and local educational efforts?
- Which organisations can you partner with to further educational objectives?
- How do you maximise resource allocation for education?
- Who needs to be involved in the development of educational activities (local teachers, elders, etc)?
- What are the various goals and objectives of different stakeholders?
- What are the critical and core components needed in an educational program? And, what are the nice to haves?
- What is the local and national school context practitioners are facing?
- What is the school starting point?
- What information does the social/educational characterisation provide that might impact program development?
- What special considerations are needed, if any?
- What and when do you introduce activities in schools?
- How do you envision implementation?

Stakeholder Consideration Questions:

- What will be their role in the project?
- How can we gain a very clear understanding of the subject and the program so we can help teachers?
- How will program link to content in school?
- How will district involvement in program impact them and their learners while integrating new activities?
- How will education specialists “on the ground” be given resources?
- How will your organisation work with the District?
- What benefits and resources are available?
- How will new activities map onto existing curriculum?
- Will you provide kits for learning?
- Will you provide workshops and support for teachers?
- If learners are brought on board, are there bursaries to pursue career in climate change?
- Can there be increased interaction with international teachers who have used activities and talk to them about introducing activities into classroom?
- Can we work together to benefit adult learners as well?

Education Implementation Questions:

- When will program start?
- Do you want to bring in local municipality?
- How can we help you bring parents on board?
- What grade level is recommended for programming?
- What will the duration of program be?
- When do you plan to implement in curriculum? What unit attach to?
- What partnerships can be implemented to support teachers?
- Can you donate equipment for use, in addition of kits?
- Is there any pre-requisite learning?