Using Science to Do Social Good:

STEM Education for Sustainable Development

STEM Education for Sustainable Development encourages children and youth to draw on their STEM competence and the process of science as a key basis for reasonable action in our world. Knowledge, skills, and understanding of science, technology, engineering, and mathematical phenomena are vital to helping students understand global problems and support actions in society that address these challenges in a meaningful and knowledge-based way.

The orientation of individual actions towards certain explicit and reflective values enables us to act locally in such a way that we also take responsibility for the world around us. Children need to be considered active stakeholders in inquiry and sustainability issues and to be encouraged to become problem-seekers and solvers in their own localities.

In this spirit, STEM Education for Sustainable Development (STEM4SD Education) offerings should be oriented towards the following guiding principles:

- Promote inquiry-based learning and scientific thinking and practice.

- Encourage interactive, learner-centered teaching that enables exploratory, action-oriented, reflective and transformative learning.

- Reinforce a whole institution approach that focuses on the systemic development of the educational facility towards quality education and sustainability and considers the role of management at the school, state or government level.

- Foster independent thinking and responsible action that takes place in the learner context and involves the institution's social and natural environment, providing the opportunity to implement and experience real changes in the learners' own community, which then strengthens their capacity for agency.

- Be compatible with the goals of sustainable development.

- Strengthen evidence-based and reasoned argumentation, recognize complexity, promote diversity of opinion and change of perspectives, and encourage the critical reflection of values.

- Empower present and future generations to use science, technology, engineering, and mathematics (STEM) skills and reflective reasoning to solve complex sustainability problems.

Using Science to Do Social Good:

STEM Education for Sustainable Development[1]

Position paper developed in preparation for the second

"International Dialogue on STEM Education" (IDoS) in Berlin, December 5-6, 2019

As of: Dec 6, 2019

I.   Overview

This paper constitutes the result of an expert discussion in the international programme committee preparing the second International Dialogue on STEM[2] Education (IDoS) on the subject of "STEM Education for Sustainable Development", a conference initiated by the Foundation "Haus der kleinen Forscher" and Siemens Stiftung and taking place in December 2019 in Berlin, Germany[3]. The development of this position paper was moderated by the Foundation "Haus der kleinen Forscher". It is based on a position paper published in German, clarifying the relation between science, technology, engineering, and math education (STEM Education) and Education for Sustainable Development (ESD)[4].

The purpose of this paper is to analyze critically how an integrated and transdisciplinary[5] focus on inquiry-based STEM education, could serve to enhance sustainable development and build capacity for future generations. As such, the present paper argues for what we are calling "STEM Education for Sustainable Development" (STEM4SD Education), promoting an idea of STEM Education in a transdisciplinary framework, acknowledging the complex context of global challenges and the need for integrating values, ethics, and world views towards the development of sustainability mindsets and using science to do social good. After reviewing the context and pedagogical basis of this approach, the paper presents a set of goals and guiding principles of STEM4SD Education.

This paper reflects the current state of thinking and discussion on the topic, as shared among the involved international experts. As the dialogue with experts from science and practice continues, future adjustments are possible.

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[2] "STEM" stands for science, technology, (information) engineering, and mathematics. We define STEM Education as an education combining science, technology, (information) engineering, and math concepts and methods in an integrated way that transforms the discipline of science.
[3] https://www.haus-der-kleinen-forscher.de/en/international-dialogue-on-stem-education/idos2019/
[4] Stiftung Haus der kleinen Forscher (2018). *MINT-Bildung und Bildung für nachhaltige Entwicklung (STEM Education and Education for Sustainable Development).* Berlin: Stiftung Haus der kleinen Forscher. See: https://www.haus-der-kleinen-forscher.de/fileadmin/Redaktion/4_Ueber_Uns/Stiftung/2018_Positionspapier_MINT-Bildung_fuer_nachhaltige_Entwicklung_HdkF.pdf
[5] *transdisciplinary* – for the purposes of this project, we define *"transdisciplinary"* (different disciplines working under a shared conceptual framework and drawing together theories, concepts and approaches that transcend individual disciplinary boundaries to collectively address a common problem), as being distinct from both *"multidisciplinary"* (different disciplines working independently on different aspects of the same project), and *"interdisciplinary"* (integration of participating disciplines). For the full definitions, see page 103 of the 2009 article by Audrey Collins "Multidisciplinary, interdisciplinary, and transdisciplinary collaboration: implications for vocational psychology" in the *International Journal for Educational and Vocational Guidance,* and the 2017 Dissertation Abstract from UC San Diego "An Application of Multidisciplinary, Interdisciplinary, and Transdisciplinary Approaches in Collaboration" (available from: https://escholarship.org/uc/item/3cc9j6jp).

II.   The Global Challenge: The Need for Sustainable Development

Teenagers and students worldwide get together in the movement "Fridays for Future"[6] and call for sustainable solutions for global challenges such as the climate crisis. (Note that for this paper, we define *sustainability* as "avoidance of depleting natural resources to meet today's needs without sacrificing access to those resources in the future".)[7] They request politicians to comply with international agreements for climate protection (such as the Paris Agreement[8]) and to promote political solutions for living and acting within the planetary boundaries. The physical realities of the climate crisis make the relevance of sustainable development impressively recognizable[9].[10]

But climate change alone is not the only issue we face that must be addressed through policy, education, and action. Many complex scientific phenomena exist within societies, including microplastics in oceans, biodiversity loss, over consumption and production, glacial melt in the Arctic, food insecurity, extreme hurricanes and floods, and climate-induced migration. Informed students demand that adults take into account the scientific findings about these phenomena and act accordingly. Scientists such as the InterAcademy Partnership[11] and "Scientists for Future"[12] support this concern.

In 2015, the United Nations Development Programme (UNDP) identified a series of seventeen important worldwide goals referred to as the Sustainable Development Goals (SDGs). These goals make up a blueprint for the future well-being of the planet and its inhabitants. Adopted by all member States in January 2016, the 17 goals (made up of 169 targets and 232 sub-indicators) provided a 15-year aspiration (2015 – 2030) for the globe oriented around the themes of people, planet, prosperity, peace, and partnership[13]. These goals place emphasis on human rights and inclusion of all, and attempt to balance the scientific environmental needs for a sustainable planet, with the economic, social, ethical, (and often political) dimensions of the problem.

Thus, movements in society and science call for a transformation into more sustainability. The world community is struggling for answers. Target conflicts between economic, political, ecological, social and cultural aspects occur and need weighted approaches that often must be invented first. These "wicked" issues[14] require discussions and solutions that consider different perspectives, address values, and find ways to handle ambiguity and dilemmas.

While science alone cannot provide exhaustive solutions, scientific insights about physical, chemical, biological, or social interconnections are a vital element for responsible actions based on reflected knowledge. By educating youth on these socio-scientific issues from a young age, and engaging them in perspective-taking, we can address and act on the most complex issues of our time and the generations to come.

III.   The Need for a Future-Oriented STEM Education

Schools today face the impacts of urban migration, cultural diversity, digital divide, and often low-qualified teachers; yet, there is an explosion of scientific knowledge and exponential changes, which demand that schools prepare students to be scientifically literate[15].

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[6] https://www.fridaysforfuture.org/
[7] UN. (1992). Conference on Environment & Development. Retrieved: https://sustainabledevelopment.un.org/content/documents/Agenda21.pdf
[8] United Nations Framework Convention on Climate Change (UNFCCC). In 2016, the Paris Agreement entered into force. https://unfccc.int/process-and-meetings/the-paris-agreement/the-paris-agreement
[9] Nationale Akademie der Wissenschaften Leopoldina (2019). https://www.leopoldina.org/presse-1/nachrichten/klimaziele-2030/
[10] IPCC reports, see https://www.ipcc.ch/
[11] "A Statement on Climate Change and Education from the member academies of IAP for Science." file:///C:/Users/Admin/Downloads/WEBIAPStatementClimateChangeEdu2017_.pdf
[12] https://www.scientists4future.org/
[13] United Nations. (2019). *New SDG Advocates Sign up for "Peace, Prosperity, People, and Planet, on the Road to 2030*. Retrieved: https://news.un.org/en/story/2019/05/1038202
[14] Dillon, J., Stevenson, R. B., Wals, A. E. J. (2016). Moving from citizen to civic science. *Conservation Biology, 30*(3), 450-455.
[15] O'Donnell, C. (2018). Science Education, Identity, and Civic Engagement: Empowering Youth through the UN Sustainable Development Goals. In A. Rold (Ed.), *G7: The Executive Talk Series Global Briefing Report* (pp. 108-116). Carlevoix, Canada: Diplomatic Courier.

Globalization indicates that the problems of one country affect everyone; therefore, educating all children to be responsive to the issues of the day is critical. As Emmanuel Nnandozie, of the African Capacity Building Foundation notes, "real transformation will not happen unless countries give real priorities to STEM" education[16]. A powerful and sustained implementation of future-oriented science, technology, engineering, and math (STEM) education focused on the issues of critical importance, such as those outlined in the UN SDGs, and potential solutions to those problems, will help to inoculate young people and their teachers and parents against societal and health problems that can adversely affect their lives[17].

The future inhabitants of the planet need the knowledge, abilities, and agency to think and act responsibly. Children and teenagers need an education orienting them in a world of uncertainty and rapid change and helping them navigate and design the future[18]. Education is a crucial part of the SDGs, not only due to its role as a specific goal (Goal 4: Quality Education), but also because it is essential to the possibility of progress on all goals.[19] Ensuring that all learners acquire the knowledge and skills to promote sustainable development is explicitly addressed in SDG 4.7.

However, the consensus of the nature and format of the education needed for progress on the SDGs is still coalescing. Many of the ambitious goals specified by the SDGs will require concerted action at all levels, including local ones[20]. To be successful, SDG-related education needs to both inspire and inform this action[21]. In addition, since the SDGs have identified solutions to the world's most complex wicked problems[22], which are not easily solved, future-oriented SDG-related STEM education needs to promote long-term engagement on these global goals.

Future-oriented education initiatives should encourage people to engage with the often complex sustainable development issues and to take different perspectives into account; e.g. to reflect on ways in which a good quality of life for everyone everywhere can be ensured.

STEM Education should help students solve the global challenges of our generation. Engagement with science, technology, engineering, mathematics, and computer science – in addition to languages, the arts or social-emotional learning – should be an integral part of future-oriented education to which every child and every young person has a right. It supports independent thinking and responsible action, as well as the reflective engagement with technological and societal changes for the benefit of sustainable development.

Education for Sustainable Development (ESD) encourages changes in knowledge, skills, values and attitudes to enable a more *sustainable* and just society for all. It aims to empower and equip current and future generations to meet their needs using a balanced an integrated approach to sustainable development[23].

We argue that future-oriented STEM Education should focus on engaging youth in *both* scientific investigation and action on the most pressing issues of our time. To build our case, we will tackle each of the following separately—STEM and Research in Society, Inquiry-based STEM Education, and Education for Sustainable Development. We will also provide a description, framework, and examples for how to integrate STEM Education and Education for Sustainable Development to achieve what we are calling STEM4SD Education.

[16] Pontificiae Academiae Scientiarum (PAS). (2015). *Children and Sustainable Development: A Challenge for Education.* Vatican City, Rome. Retrieved July 6, 2016 from: http://www.casinapioiv.va/content/accademia/en/events/2015/children.html

[17] O'Donnell, C. (2018). Science Education, Identity, and Civic Engagement: Empowering Youth through the UN Sustainable Development Goals. In A. Rold (Ed.), *G7: The Executive Talk Series Global Briefing Report* (pp. 108-116). Carlevoix, Canada: Diplomatic Courier.

[18] OECD Framework "Future of Education and Skills 2030". https://www.oecd.org/education/2030-project/

[19] UNESCO. (2014). *Aichi-Nagoya Declaration on Education for Sustainable Development.* Retrieved: https://sustainabledevelopment.un.org/content/documents/5859Aichi-Nagoya_Declaration_EN.pdf

[20] Gibson, H., Blanchard, K.P., & O'Donnell, C. (in press). *Learning to act:* Smithsonian Science for Global Goals *and empowering young people to develop a habit of considered action-taking.* In Tonya Huber (Series Ed.) International Education Inquiries: People, Places, and Perspectives of Education 2030: Vol. 3. Charlotte, NC: Information Age.

[21] Sterling, Stephen. (2016). A commentary on education and sustainable development goals. *Journal of Education for Sustainable Development*, *10*(2), 208–213. https://doi.org/10.1177/0973408216661886

[22] Dillon, J., Stevenson, R. B., Wals, A. E. J. (2016). Moving from citizen to civic science. *Conservation Biology, 30*(3), 450-455.

[23] https://en.unesco.org/themes/education-sustainable-development

IV.   Value of STEM & Research in an Enlightened Society

The research disciplines underlying STEM Education are committed to the ideal of knowledge discovery and freedom of research. By means of scientific methodology and reflection, they strive for intersubjectively understandable statements and findings. Scientists explore and observe, they ask questions, try to discover connections and to understand phenomena in the world. They discuss findings and their implications, as well as the limitations of methods and knowledge. In research, the access to, and the application and exploitation of findings, and the possible ecological and/or societal consequences associated therewith, are discussed. Thus, discussions on ethics and values are an integrated part of science. In 2019's Lindau Nobel Laureate Meeting, for example, the role of science and scientists in society was a major topic in the keynote address during the opening ceremony [24],[25].

Moreover, science and research move in their respective historical and social contexts and influence social developments. Researchers are citizens of countries with political and social systems, and, as such, they are not independent from values and laws in their actions. Technological impact assessment takes account of this. The historical and social context is changing. Documents such as the Agenda 2030 [26] and the concept of planetary boundaries[27] describe the load limit of the planet and the need for transforming society in the direction of sustainable development.

The STEM disciplines are called upon to participate in the social process of searching, learning, and shaping with the aim of solving global sustainability issues and to critically reflect on their contribution to (non-)sustainable developments. STEM knowledge and the process of science can help understand global problems and support actions in society that address them in a meaningful and knowledge-based way.

V.   Inquiry-Based STEM Education

In the concept of STEM Education, a "scientific" or inquiry-based approach to natural phenomena corresponds to that of tapping into children's inquisitiveness and thirst for exploration, into their desire to get to the bottom of things and to ask questions, and into the basic human need to appropriate the world through understanding.

Inquiry-Based Science Education (IBSE) and more recently "Inquiry-Based STEM Education" are both built on constructivist theories of learning by Piaget and Vygotsky, namely that children (as well as adults) form their understanding of the world based on the knowledge that they acquire over time, and new knowledge augments previous understandings[28]. Constructivism has long been applied to many different education disciplines, but has become particularly relevant to IBSE and more specifically STEM Education, which "gives children the opportunity to explore 'hands on', to experiment, to ask questions, and to develop responses based on reasoning"[29] in addition to solving problems, and understanding

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[24] Schmidt, B. (2019). *Big Questions for Society, Big Questions for Research.* Keynote address during 2019's Lindau Nobel Laureate Meeting opening ceremony. https://www.mediatheque.lindau-nobel.org/videos/38253/keynote-address-brian-schmidt-2019/meeting-2019

[25] https://www.lindau-nobel.org/blog-how-science-can-tackle-the-united-nations-sustainable-development-goals/

[26] General Assembly of the United Nations, 18 September 2015: Transforming our world: The 2030 Agenda for Sustainable Development. Retrieved from https://sustainabledevelopment.un.org/post2015/transformingourworld

[27] Rockström, J., Steffen, W., Noone, K., Persson, Å., Chapin, F.S. III, Lambin, E. et al. (2009). Planetary Boundaries: Exploring the Safe Operating Space for Humanity. *Ecology and Society, 14* (2). Retrieved October 17, 2019 from http://www.ecologyandsociety.org/vol14/iss2/art32/

[28] Feldman, D. H. & Fowler, C. (1997). The nature(s) of developmental change: Piaget, Vygotsky, and the transition process. *New Ideas in Psychology, (15)3,* 195-210. https://doi.org/10.1016/S0732-118X(97)10001-0

[29] O'Connell, Claire. (2014). *Inquiry-based science education: Primer to the international AEMASE conference report.* Berlin, Germany: All European Academies (ALLEA). https://www.allea.org/wp-content/uploads/2015/09/AEMASE-conference-report_Primer_digital.pdf

the phenomena of the natural world around them ('minds on'), just as scientists and engineers do.

In recent years, there has been a rapid expansion of interest in both IBSE and STEM education across the globe that has been supported by businesses, policy makers, and non-governmental actors such as the InterAcademy Partnership Science Education Programme (IAP-SEP). While modern science education has evolved over the last century, the consistent goal has been to address the ills and challenges of society[30], and that has not changed even with the emergence of STEM education or the rise of ESD. Creating a skilled and successful workforce is a compliment to creating global problem solvers. The two are bound together, and demand that even those not seeking STEM careers have a basic foundation of scientific literacy - the ultimate (if unspecified) goal of most science education programs.

STEM Education offerings should support the acquisition of skills for the 21st century, as outlined, for example, by the OECD in its Learning Framework for 2030.[31] Many good practice initiatives develop their offerings on the basis of a co-constructive understanding of learning, across three domains—cognitive, social, and behavioural. Exploration and exploration-based and inquiry-based learning are paths to knowledge for children and pedagogues, on which they can build up knowledge and skills.

The goals of early science education comprise the dimensions of motivation, understanding of basic science concepts, procedural knowledge about, and skills in, scientific working methods, thus leading to "Scientific Literacy"[32]. Since its first introduction into educational vernacular, scientific literacy has held a space somewhere between educating young people with deep scientific content knowledge, and arming them with the skills and practices of science that are translatable to other disciplines[33]. Like action, scientific literacy is not merely about knowing information. It is instead what a person chooses to do with this.

Therefore, besides conceptual knowledge, an essential part of basic education in the STEM domains is the ability to acquire, expand, critically reflect on, and apply knowledge using suitable methods of thinking and acting. This includes the ability to work out fundamental relationships for oneself, to evaluate these relationships, and to make decisions based on them.[34] Thus, the evaluation of scientific results includes questions of value orientation.

It is our contention, therefore, that high quality inquiry-based STEM Education should take the social context into account. It should strive to let STEM knowledge flow into meaningful actions for the common good and deal with the values and debates needed to allow this.[35] Hence, inquiry-based STEM Education should aim to comprehensively understand the world and to apply in a value-based way what has been learnt. Thus, modern STEM Education pursues a critical-emancipatory understanding of education.

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[30] DeBoer, G. (2019). *A history of ideas in science education.* New York: Teachers College Press.
[31] OECD Learning Framework for 2030. Retrieved from http://www.oecd.org/education/2030/learning-framework-2030.htm
[32] "Haus der kleinen Forscher" Foundation (Ed.). (2017). *Early Science Education. Goals and Process-Related Quality Criteria for Science Teaching. Scientific Studies on the Work of the "Haus der kleinen Forscher" Foundation* (Vol. 5). Opladen, Berlin, Toronto: Verlag Barbara Budrich. See: www.haus-der-kleinen-forscher.de
[33] DeBoer, G. (2019). Ibid.
[34] "Haus der kleinen Forscher" Foundation. (2016). *Pedagogic Approach of the "Haus der kleinen Forscher" Foundation. A Guide to Facilitating Learning in Science, Mathematics, and Technology*. 5th edition. See: www.haus-der-kleinen-forscher.de
[35] See, for example, Siemens Stiftung (Ed.) (2016). Science, technology, and values guideline. Methods for implementing the value aspects in science and technology lessons with Experimento I 8+. Munich: Siemens Stiftung

VI.   Education for Sustainable Development (ESD)

Education for Sustainable Development (ESD) is defined as an "interdisciplinary learning methodology covering the integrated social, economic, and environmental aspects of formal and informal curriculum".[36] ESD is compatible with other fields of education, such as science education, environmental education, intercultural education, democracy and citizenship education, and community-based education[37]. It attempts to integrate them by means of child-centered approaches, in order to build a consistent framework to address the current socio-environmental crisis.

Against a view of young children as not ready to be taught about critical societal issues, the literature tends to agree not only about the pertinence of ESD in early-childhood, but also on the necessity to foster child-centered approaches to start the development of abilities, attitudes, and values for sustainable development from an earlier age.[38]

Goals of Education for Sustainable Development (ESD) for children and for pedagogical staff and managers in early education comprise motivation, understanding and knowledge, reflection and evaluation, values and moral options, and action, as follows:[39]

- *Motivation:* To develop interests, for example in climate issues or social justice, and to experience self-efficacy, for example in engaging with these issues at the local level.

- *Understanding and knowledge:* To understand basic concepts and to build up knowledge.

- *Reflection and evaluation:* To recognize problems (e.g., non-sustainable development), understand perspectives, and engage in constructive discussions.

- *Values and moral options*: To experience values and the negotiation of and reflection on value standards, thereby initiating the development of a reflective attitude of critically examining and applying moral norms and, in the long term, the ability to make ethical judgments.

- *Action:* To participate in decisions, negotiate solutions, and change something in their everyday lives.

Like the approaches of inquiry based-learning, ESD is based on a co-constructivist understanding of learning. Key methods of ESD are exploration-based, inquiry-based, and dialogic learning, as well as philosophising with children.

Inquiry-based questioning in ESD takes the ecological, economic, and sociocultural dimensions into account and supports children in recognizing complexities and learning to constructively and courageously handle ambiguity and dilemma situations. While espousing an essential openness of the learning outcomes, ESD broaches values such as respect for

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[36] "Education for Sustainable Development". *UNESCO*. Retrieved: https://en.unesco.org/themes/education-sustainable-development

[37] Community-based inquiry is defined as authentic project-based inquiry that is related to a particular community need. See: Quitadamo, I. J., Faiola, C. L., Johnson, J. E. & Kurtz, M. J. (2008). Community-based inquiry improves critical thinking in general education biology. *CBE Life Sciences Education, 7*(3), 327-337. Available: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2527977/

[38] Bascopé, M., Perasso, P., Reiss, K. (2019) Systematic Review of Education for Sustainable Development at an Early Stage: Cornerstones and Pedagogical Approaches for Teacher Professional Development, Sustainability, 11 (3), 719 Available: https://www.mdpi.com/2071-1050/11/3/719/htm#

[39] Kauertz, A., Molitor, H., Saffran, A., Schubert, S., Singer-Brodowski, M., Ulber, D. & Verch, J. (2019). Zieldimensionen einer Bildung für Nachhaltige Entwicklung (BNE) für Kinder, pädagogische Fachkräfte und Leitungskräfte. In Stiftung Haus der kleinen Forscher (Ed.), *Frühe Bildung für nachhaltige Entwicklung – Ziele und Gelingensbedingungen. Wissenschaftliche Untersuchungen zur Arbeit der Stiftung Haus der kleinen Forscher* [Goals of Education for Sustainable Development (ESD) for Children, Pedagogical Staff, and Managers. In "Haus der kleinen Forscher" Foundation (Ed.), *Early Education for Sustainable Development. Scientific Studies on the Work of the "Haus der kleinen Forscher" Foundation*]. Opladen, Berlin, Toronto: Verlag Barbara Budrich. Due for publication in 2019. See: www.haus-der-kleinen-forscher.de

nature, provision of the natural basic needs, a healthy living environment for all people, and social justice.

Education for Sustainable Development should observe critically educational practices of indoctrination or transmission of simple action rules. While regulations and laws in politics and economics can be important instruments to promote sustainable development, in education the methodologies should center on developing everyday actions in a participatory manner by means of knowledge acquired and decisions made in an inquiry-based and independently reflective way. Key topics of sustainability and ESD (e.g., nutrition, clean water, social justice etc.) are topics of long-term importance; they are globally and locally relevant; they offer opportunities for action; and they can be addressed only through an interdisciplinary or transdisciplinary lens.

The global environmental situation demands an education that will promote agency starting as early as possible, with "agency" being defined as "something that children achieve together in transactions rather than something they possess."[40],[41]. The development of agency is considered of major importance for ESD[42]; however, as research shows, it has hardly been put into practice[43]. Environmental education based mainly on transmission of declarative knowledge has not led to behavioral change on sustainability issues. In order to raise change-agents with ESD, particularly from early-childhood, education needs to focus on promoting meaningful experiences for developing agency[44],[45].

Therefore, we cannot overstate the importance of learning environments that focus on developing experience. These learning environments can be at school or at home, in formal learning spaces like schools, or in informal learning spaces such as museums or science centers. As stated in the 2009 special review of ESD for ECE "Early Childhood Education for Sustainability: Recommendations for Development", children, teachers, and all actors in the education community need to practice sustainability daily (e.g., through recycling, gardening, energy production), and not just through teaching[46].

[40] Caiman, C. & Lundegard, I. (2014). Pre-school children's agency in learning for sustainable development. *Environmental Education Research, 20*(4).

[41] Boyd, D. Early childhood education for sustainability and the legacies of two pioneering giants. *Early Years* 2018, *38*, 227–239.

[42] Davis, J. Revealing the research 'hole' of early childhood education for sustainability: A preliminary survey of the literature. *Environ. Educ. Res.* 2009, *15*, 227–241.
Caiman, C.; Lundegard, I. Pre-school children's agency in learning for sustainable development. *Environ. Educ. Res.* 2014, *20*, 437–459.
Sawitri, D.R. Education for sustainable development: How early is too early? *Adv. Sci. Lett.* 2017, *23*, 2559–2560.

[43] Ärlemalm-Hagsér, E. Minds on Earth Hour—A theme for sustainability in Swedish early childhood education. *Early Child Dev. Care* 2013, *183*, 1782–1795.
Eriksen, K.G. Why education for sustainable development needs early childhood education: The case of Norway. *J. Teach. Educ. Sustain.* 2013, *15*, 107–120.

[44] Eriksen, K.G. Why education for sustainable development needs early childhood education: The case of Norway. *J. Teach. Educ. Sustain.* 2013, *15*, 107–120.

[45] Caiman, C.; Lundegard, I. Pre-school children's agency in learning for sustainable development. *Environ. Educ. Res.* 2014, *20*, 437–459.

[46] O'Gorman, L. Sustainability, the Arts and Big Numbers: The Challenge of Researching Children's Responses to Chris Jordan's Images. *International Journal of Early Childhood*, 2017, *49* (3), 312-332.

VII. An Integrated Approach: STEM Education for Sustainable Development (STEM4SD Education)

We argue that STEM Education for Sustainable Development encourages children and youth to draw on their STEM competence and the process of science as a key basis for reasonable action in our world. Knowledge, skills and understanding of science, technology, engineering, and mathematical phenomena are vital to help students understand global problems and support actions in society that address these challenges in a meaningful and knowledge-based way.

The orientation of individual actions towards certain explicit and reflective values enables us to act locally in such a way that we also take responsibility for the world around us—combining our "person identity, local identity, and global identity"[47] as we use our STEM knowledge to do social good. STEM4SD Education can promote raising reflective change-agents to impact their communities and society through a knowledge-based, action-oriented, participatory, and integrative focus[48]. To create environments that foster agency through inquiry-based learning, STEM4SD Education must integrate STEM fields of knowledge and experience with social and emotional learning and civic engagement[49] Children need to be considered active stakeholders in inquiry and sustainability issues and to be encouraged to become problem-seekers and solvers in their own localities[50].

This relates to the relevance of scientific literacy among young children. They need to learn to undertake science, to acquire scientific competences through practice, which presupposes the integration of fields of knowledge (interdisciplinarity) to address practical issues, for example, taking into account student questions on climate change into relevant science teaching[51]. Furthermore, STEM4SD Education can be linked to the active involvement of the local community. This calls for integrating science-based knowledge and its value for society with other forms of knowledge (technology, engineering, mathematics, history, art, culture, etc.) present in the locality in a way that transcends any one discipline on its own to collectively address a common problem (i.e., transdisciplinary).

STEM4SD Education reinforces a systemic approach that - in accordance with a "whole institution approach"[52] - focuses on the development of the educational facility as a whole and considers not only the role of the early childhood educators or primary teachers but also school leaders, district or state leaders, or other decision makers at the management level or ministry of education[53]. STEM4SD Education also promotes advocacy for not just workforce development (a traditional argument of why STEM Education matters) but for developing students' critical thinking and sustainability mindsets, habits of using scientific evidence to justify sustainable practices, and understanding of the value of STEM Education for society as a whole.

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[47] Blanchard, K. P., Gibson, H., & O'Donnell, C. (2019). *Understanding yourself as a foundation for exploring the world.* In Andy Smart, Margaret Sinclair, Aaron Benavot, Jean Bernard, Colette Chabbott, S. Garnett Russell, and James Williams (Eds): *NISSEM Global Briefs: Education for the Social, the Sustainable and the Emotional*. Available: https://www.nissem.org/globalbriefs

[48] Hirst, N. Education for sustainability within early childhood studies: Collaboration and inquiry through projects with children. *Education 3-13* 2019, *47*, 233–246.

[49] O'Donnell, C. (2018). Science Education, Identity, and Civic Engagement: Empowering Youth through the UN Sustainable Development Goals. In A. Rold (Ed.), *G7: The Executive Talk Series Global Briefing Report* (pp. 108-116). Carlevoix, Canada: Diplomatic Courier.

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Initiatives following an approach of STEM4SD Education take into account the sustainable development goals of the global community. Thus, a sustainability perspective is not just an expansion of thematic offerings in STEM education initiatives. The engagement with (sustainability) goals and values in education is a broadening of discourse in the STEM Education approach of inquiry-based learning, fostering knowledgeable and responsible action for common good that is based on what we know from STEM Research and Society.

In this spirit, STEM Education for Sustainable Development (STEM4SD Education) offerings should be oriented towards the following **guiding principles**:

➢ Promote inquiry-based learning and scientific thinking and practice.

➢ Encourage interactive, learner-centered teaching that enables exploratory, action-oriented, reflective and transformative learning.

➢ Reinforce a whole institution approach that focuses on the systemic development of the educational facility towards quality education and sustainability, and considers the role of management at the school, state or government level.

➢ Foster independent thinking and responsible action that takes place in the learner context and involves the institution's social and natural environment, providing the opportunity to implement and experience real changes in the learners' own community, even on a small-scale, which then strengthens their capacity for agency.

➢ Be compatible with the goals of sustainable development.

➢ Strengthen evidence-based and reasoned argumentation, recognize complexity, promote diversity of opinion and change of perspectives, and encourage the critical reflection of values.

➢ Empower present and future generations to use science, technology, engineering, and mathematics (STEM) skills and reflective reasoning to solve complex sustainability problems.

VIII. How to Make it Work? A Framework and Examples of Practical Approaches

STEM4SD Education emphasizes the importance of developing student abilities to draw connections between the global and local. A systems approach helps young people see both the vertical (global-local) and horizontal (inter-dimensional) integration of problems and solutions[54]. It also benefits young people by building the skills to identify cause and effect.[55] Moreover, as young people become more capable of seeing connection, they also can see connections between various goals and actions, including that a number of the SDGs themselves support each other. [56]

This section provides an example framework for practical application with youth and their pedagogues and references diverse examples from six continents (not supposed to be a complete list) of how to make STEM4SD Education work in the classroom. At the International Dialogue on STEM Education (IDoS) in 2019, initiatives from all over the world meet, raising the potential of early STEM education for a more sustainable future.[57]

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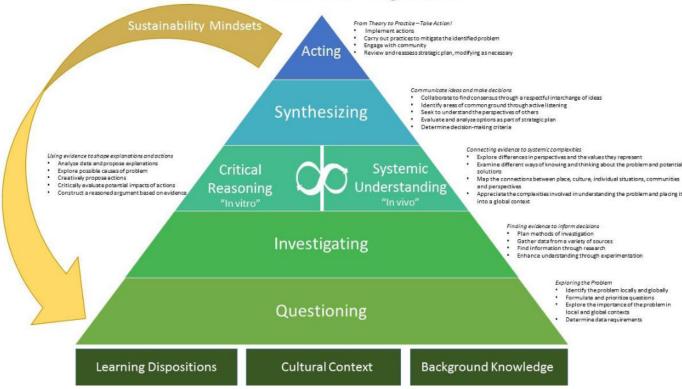
[57] https://www.haus-der-kleinen-forscher.de/en/international-dialogue-on-stem-education/idos2019/initiatives-idos2019/

Smithsonian Science Education Center's Framework: "Smithsonian Science for Global Goals" (USA)

The Smithsonian Science Education Center - whose mission is to transform K-12 Education through Science in collaboration with communities across the globe - attempts to empower the next generation of decision makers capable of making the right choices about the complex socio-scientific issues facing human society. The "Smithsonian Science for Global Goals"[58] Community Research Guides, developed by the Smithsonian Science Education Center in collaboration with the InterAcademy Partnership, help youth ages 8-17 discover, understand, and act on the most pressing socio-scientific challenges of our time (such as mosquito-borne diseases[59], food security, renewable energy, biodiversity, consumption and production). These freely available guides are based on the Smithsonian's Global Goals Action Progression (Global GAP) learning model, shown in Figure 1, which combines key pieces of inquiry-based science education (IBSE), social and emotional learning (SEL), education for sustainable development (ESD), and civic engagement[60].

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Figure 1. Smithsonian's Global Goals Action Progression (Global GAP) Learning Model.
(Source: www.ScienceEducation.si.edu/global-goals)

This learning model builds a progression that helps teachers first understand students' identity, cultural context, and learning dispositions; then engages students in questioning and investigating the issue using their community as their laboratory; next supports students critical reasoning and systemic understanding of the issue from multiple perspectives; and finally promotes students as they use their new scientific knowledge to take action in their own communities. Through all of the "Smithsonian Science for Global Goals" modules, student learning teams use their understandings to develop sustainability mindsets by finding

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[58] https://www.ssec.si.edu/global-goals

[59] https://ssec.si.edu/mosquito

[60] O'Donnell, C. (2018). Science Education, Identity, and Civic Engagement: Empowering Youth through the UN Sustainable Development Goals. In A. Rold (Ed.), *G7: The Executive Talk Series Global Briefing Report* (pp. 108-116). Carlevoix, Canada: Diplomatic Courier.

common ground, building consensus, and planning and carrying out local actions for Global Goals.

As the winner of the 2018 Smithsonian Institution's Education Innovation Award, "Smithsonian Science for Global Goals" promotes the idea that transdisciplinary socio-scientific understanding has the power to drive students' agency to bring change to their local environments while helping impact global goals. Field testing of the program across 7 countries revealed a meaningful improvement in students' content knowledge and agency, demonstrating that students believe they can impact their own lives and their communities' through scientific discovery, understanding, and action. That is, through community-based STEM Education for Sustainable Development (STEM4SD Education), students discover their own identity and the identify and perspectives of their peers and their community members as it relates to the socio-scientific issue; understand firsthand the science, technology, engineering and math (STEM) concepts and practices that underlie the issue; and then act on the issue directly in their community through civic engagement.

Centre for Mathematics, Science and Technology Education (Africa)

The Centre for Mathematics, Science and Technology Education in Africa (CEMASTEA[61]) is a Kenyan public institution established in 2004 with the mandate to provide Teacher Professional Development in Mathematics and Science Education (TPD-MSE), a role that has enabled it to realize milestones in human resource capacity for quality mathematics and science education programmes across the African continent.

CEMASTEA has received continental recognition to coordinate and host continental secretariats such as the African Union Commission Continental Education Strategy for Africa (AUC-CESA, 2016–25) cluster on STEM education; the Association for the Development of Education in Africa's Inter-Country Quality Node on Mathematics and Science Education (ADEA: ICQN-MSE); and the Strengthening of Mathematics and Science Education in Africa (SMASE Africa), a network of 27 countries. These platforms enable policy dialogue to begin at the practitioners' forum, the SMASE Africa network, and move to the ministerial forum at ICQN-MSE and finally to the level of the heads of state, who draw from the CESA cluster on STEM.

CEMASTEA's work in the provision of quality STEM education through teacher training has built a foundation for education and the supply of quality workforce in support of Agenda 2030, Agenda 2063[62] and the SDGs. The agency has been able to provide guidelines and support in STEM Education that are utilized across the continent and take into consideration the local context of the instructions as well as aspects of adaptability, gender, equity, global trends and sustainability.

Sirindhorn Science Home (Asia)

In Thailand, Sirindhorn Science Home[63] is one of the national learning centres for STEM activities for teachers and children under the National Science and Technology Development Agency (NSTDA), Ministry of Higher Education Science Research and Innovation. The activities at the Sirindhorn Science Home (including teachers' training, a STEM camp and Fabrication Lab for students, and the development of curricula and science educational content and material such as books and, multimedia) aim to equip children and youth with three major qualities for a worthwhile future: inspiration, motivation, and creativity. The program encourages the development of essential skills, such as critical thinking, communication, collaboration, and creativity which are essential for sustainable development.

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[61] http://www.cemastea.ac.ke/
[62] https://www.un.org/en/africa/osaa/peace/agenda2063.shtml
[63] https://www.nstda.or.th/en/

The STEM4SD Education activities[64] at Sirindhorn Science Home for children relate to the 17 goals of sustainable development and incorporate seven pedagogies:

1) *Making it a meaningful learning experience*. For example, students who have parents in a rubber plantation career might solve the problem how to cut the tree to get maximum latex; students who have parents in a farmer career might invent a rice mill machine.

2) *Cultivating creativity through powerful ideas*. Students do various innovative projects using an interdisciplinary and transdisciplinary approach for solving the problem related to their daily life. For example, in a rural school in a Northern region, students invented the automatic feeding machine for fish, winning an award in a national competition.

3) *Allowing students to construct their own understanding and knowledge of the world*. For example, primary school students learn about climate change by exploring the environment and by creating games about this and playing it.

4) *Creating challenging activities in specific contexts*. Since children and youth differ in their learning processes, different methods are required to comprehend these differences and match learning activities. Furthermore, academic and cultural backgrounds, demographic and geographic aspects are also factored in for designing educational activities providing an encouraging and dynamic learning environment leading these young learners to new knowledge of technology and innovation.

5) *Nurturing curiosity continuously with a Learning Spiral model.* For example, studying the photosynthesis process of a plant, followed by intermediate activities of studying the wavelength of light for photosynthesis, and designing and creating a micro green box for suitable vegetable planting.

6) *Teaching children how to think rather than what to think.* For example, teachers build students' metacognitiive skills through recording, refection, and discussion.

7) *Setting an inspiring learning environment.* For example, teachers offer hands-on activities related to daily life to motivate students to bring out their inspirations for their best learning.

Primary Connections (Australia)

Australia has a coherent suite of national programs to strengthen STEM Education at all level, from early childhood education to about year 10 high school, all of which address the global sustainability goals. In Australia, the focus is specifically on sustainability goal goals like clean water and healthy marine systems, food security, resilience to extreme weather events including fires and floods, and access to quality education.

These programs are all based an inquiry-based learning and the 5Es, engage, explore, explain, elaborate and evaluate. They all focus on STEM topics as part of a sound education and in preparation of the challenges of the future. The Australian government funds the programs. The suite includes *Primary Connection*, *Science by Doing* and *reSolve - mathematics by Inquiry*, coordinated by the Australian Academy of Science, and *Little Scientists.* All these programs empower our teachers and educators and through them the students.

Primary Connections[65] provides exemplary curriculum resources and a comprehensive and practical professional learning programme, with a focus on developing students' knowledge, understanding, and skills in both science and literacy. As an evidence-based approach, it incorporates rich professional learning workshops for teachers accompanied by exemplary

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[64] For example, Biomimicry programme, Climate action programme, STEM plus culture programme, Energy and transportation programme, Food and feed programme, Agriculture programme, Robotics and automation programme, Smart material for sustainable city programme, Good health programme, and Biodiversity programme.

[65] https://www.primaryconnections.org.au/

curriculum resources. The program earned a high reputation amongst educators over decades, and has a wide reach, with many thousands of teachers using components every week. In the past it focused on printed material creating an excellent reputation and wide national following, it now focuses on professional development and in the future it is looking at all digital tools and platforms to be most effective.

Similarly, *Little Scientists (*in cooperation with *Foundation Haus der kleinen Forscher)* is working with early childhood educators, *Science by doing* is focusing on the need for practical and reliable information about experimentation in teaching laboratories in schools, and provides material and ideas directly accessible to the students. *reSolve - mathematics by inquiry* provides a pathway for mathematics education from primary to secondary school. Together they provide tools within a very diverse education system.

"Haus der kleinen Forscher" Foundation (Europe)

The non-profit "Haus der kleinen Forscher" (House of Little Scientists) Foundation is committed to high-quality early education in the domains of science, technology, computer science, and mathematics with the aim of strengthening children for the future and enabling them to act in a sustainable way[66]. Together with its local network partners in Germany, the Foundation provides a nationwide professional development programme that supports pedagogical staff at more than 32,000 early childhood education and care centres, after-school centres, and primary schools in facilitating the exploration, inquiry, and learning of children between the ages of three and ten. Partners of the "Haus der kleinen Forscher" Foundation include the Helmholtz Association of German Research Centres, the Siemens Stiftung, the Dietmar Hopp Stiftung and the Deutsche Telekom Stiftung. The German Federal Ministry of Education and Research has supported the initiative since 2008.

The mission of the "Haus der kleinen Forscher" Foundation is to promote a questioning and inquiring attitude in children; to give children the opportunity to discover at a young age their own talents and potential in the domains of science, technology, computer science, and mathematics; and, by so doing, to lay the foundations for reflective engagement with technological and social changes in the interests of sustainable development. The "Haus der kleinen Forscher" Foundation's pedagogic approach focuses on the interests and abilities of the children and emphasises collaborative, inquiry-based learning in dialogic exchange[67].

The "Haus der kleinen Forscher" Foundation supports educational institutions in developing as a whole institution by establishing a STEM4SD Education focus and offering children favourable development and learning environments. With its activities, the Foundation supports the implementation of existing education plans in the domains of science, technology, computer science, and mathematics as well as ESD. For example, teachers support children to explore basic forms of energy by inquiring hibernating animals. Children learn about heat insulation and how to air rooms in a way that enables good exchange of air without wasting energy. The professional development programme of the initiative is mentioned in the UNESCO report about the implementation of SDG 4 worldwide[68].

All activities of the education initiative are research-based and evaluated on an ongoing basis. The "Haus der kleinen Forscher" Foundation as a learning organisation engages in open dialogue with scientists and professional practitioners, and collaborates internationally with several countries. The Foundation contributes to expert groups such as the expert forum driving forward the UNESCO Global Action Programme (GAP) on ESD in Germany[69]. This forum has developed and is currently implementing the National Action Plan on ESD in Germany.

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[66] https://www.haus-der-kleinen-forscher.de/en/
[67] https://www.haus-der-kleinen-forscher.de/en/practice/
[68] *Beyond commitments – How countries implement SDG 4* (2019). A special publication on the occasion of the 2019 High-level Political Forum, prepared by the Global Education Monitoring Report team under the auspices of the SDG-Education 2030 Steering Committee. https://unesdoc.unesco.org/ark:/48223/pf0000369008/PDF/369008eng.pdf.multi
[69] https://www.bne-portal.de/en/german-national-action-plan/gap-implementation-structures-germany

***Experimento* / Siemens Stiftung (Europe)**

With the international education program Experimento for educators and teachers, Siemens Stiftung is committed to value-oriented science and technology education that starts in kindergarten and continues all the way through graduation.[70] The program focuses on independent experimentation, exploration, and comprehension of natural phenomena pertaining to energy, environment, and health. By addressing value-shaping issues and using socially-relevant teaching and learning formats, the lessons are meant to teach attitudes and behaviors that are socially-aware, conscientious and lead to sustainable development in both, society and environment. The lesson materials created for this purpose are available digitally. They are free of charge and openly licensed (OER) to allow as many people as possible around the world access to high-quality education.[71]

Interest in science and technology knows no borders: The education program Experimento is now helping teachers in 13 countries give children and young people the skills they need for a successful future. In multi-day workshops, trainers show how to prepare exciting experiments with simple materials and how to implement them in a didactically appealing way in science and technology classes.

The program's content is adapted to circumstances in each country or integrated into the existing education system through close cooperation with universities, teacher training institutions, schools, vocational training centers, foundations, bilateral and multilateral institutions, and public authorities. This creates effective synergy and a lively cycle of new ideas.

***Office for Climate Education (OCE) - An international initiative for climate change education* (Europe)**

The Office for Climate Education (OCE)[72] was created in 2018 in order to promote a strong international cooperation between scientific organisations, education institutions and NGOs, with the aim of educating the young generations of today and tomorrow about climate change. These new generations will have to be prepared to live in a changing world. Hence, the OCE aims at providing them with the tools they need to understand and act, and to be aware of received ideas and avoid irrationality.

The OCE and its partners produce education resources and provide professional development and support to teachers around the world, particularly in developing countries. Based in Paris, the operational OCE team coordinates a worldwide network of local and regional partners. This network is supported by both the scientific community (research institutions, academies of sciences, ...) and various NGOs, which contribute with their expertise to the production of education resources and to the professional development and field support of teachers. This community of practice ensures that schools get moving to face future challenges in a sustainable and holistic way, deeply rooted in their social environment and local communities. The resources proposed by the OCE and his partners include inquiry-based learning activities, such as investigation-based activities, project-based learning, role-playing games, debates, etc. These resources aim at promoting action and positive thinking, keeping in mind the social issues that are inherently linked to climate change adaptation and mitigation challenges.

The OCE helps public institutions in charge of conceiving and defining public education policies related to sustainable development, with a focus on the inclusion of the climate-change topic in school curricula and/or teachers' professional development, thus supporting education policy-making.

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[70] https://www.siemens-stiftung.org/projects/experimento/
[71] https://medienportal.siemens-stiftung.org/experimento_matrix&changelang=en?id=experimento_matrix
https://medienportal.siemens-stiftung.org/experimento
[72] http://www.oce.global/en/node/8

StarT (Europe)

In StarT[73] in Finland, students carry out projects related to science, technology, or mathematics, and teachers get support for the implementation of interdisciplinary and collaborative project-based learning. In order to spread innovations made in classrooms around the world, StarT shares and gives awards to the most distinguished student projects and teachers' best educational practices annually. StarT's main goal is to work towards a better future by promoting children's STEM and 21st century skills through the international StarT programme. As such, the StarT projects empower children to use STEM to solve issues related to sustainability, showing them that they can actively contribute to a better future. Furthermore, StarT offers, for example, massive open online courses (MOOCs), a material bank, a virtual club, and StarT ambassadors. Associated StarT is organized by the LUMA Centre Finland.

Pontificia Universidad Catolica de Chile, Campus Villarrica (South America)

At its Villarrica Campus[74], Pontificia Universidad Católica de Chile offers certification to pre- and in-service teachers by providing courses covering the topics inquiry-based learning, the science of sound, pedagogical approaches for the 21st century, and project-based learning. All of these courses consist of lectures and practical work at schools. The educational activities are planned by the schools in collaboration with the university, taking into account their necessities and capacities. Last year, the Villarrica Campus complemented the above-mentioned certifications with a diploma focusing on Education for Sustainable Development. The diploma seeks to enable teachers to give the children opportunities to shape local change and, by giving them more contextualized experiences, to transform their own realities towards a more sustainable world.

Also a pedagogical strategy to establish a dialogue between scientific and indigenous knowledge has been developed in Villarrica, situated in the Araucanía region which concentrates the highest proportion of Mapuche indigenous people in the country. The adaptation called "Epu Trokin Kimun"[75] (Exchange among two knowledges in mapuche language) provides educational resources to implement pertinent and place-baced project-based learning activities. Free educational resources to foster research along with some real cases examples are available in the website to foster more initiatives at schools.

STEAM Territories / Siemens Stiftung (South America)

In STEAM Territories, actors of civil society, science, economy and state unite and form local alliances in order to foster and strengthen the STEAM education throughout the education chain in a geographically defined space. This systemic approach aims on specific local contexts and problems, to respond to global challenges like the promotion of science and technology education, the stimulation of 21st century skills as well as an integral sustainable development in both, society and environment. By hosting many innovative education programs, the STEAM Territories can be referred to as strong incubators for education innovation.
The idea of the STEAM Territory is based on the experience of the German network model "MINT Regionen", which is conducted by the Koerber Stiftung and the National STEM Forum Germany. Siemens Stiftung adapted this network-model internationally and initiated the STEAM Territory project in Latin America, where until now six STEAM Territories are already operating: STEAM Territory Valparaiso (Chile), STEAM Territory Macrozona Sur (Chile), STEAM Territory Arequipa & Cajamarca (Peru), STEAM Territory Lima Metropolitana (Peru), STEM+H Territory Medellin (Colombia) and STEM Territory State of Mexico (Mexico).

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[73] https://start.luma.fi/en/
[74] http://www.villarrica.uc.cl/
[75] www.eputrokinkimun.org

These examples from all over the world show approaches of how to make STEM4SD Education work in the classroom. They take into account the sustainable development goals and pursue a pedagogy that match the guiding principles outlined above. In Peru, for example, the approach "Mathematics and Communication for All" uses the following criteria when talking about STEAM actions related to sustainable development to support teachers to practice it in the classroom:

- Minimum integration of at least two STE(A)M disciplines.
- Learning in class sessions takes, as a starting point, the context of real life
- Activities promote the resolution of a challenge, a problem, and a need and encourage children to be problem-seekers.
- Incorporates active learning and doing methodologies (e.g. inquiry-based learning, learning in projects).
- Generation of a final product that positively impacts a problem of the context.
- Promotes self-learning.
- Links the SDGs and promotes 21st century competencies.
- Encourages group work that contributes to reflection, decision making and learning construction.

Thus, many initiatives worldwide have started raising the potential of early STEM education for a more sustainable future. They show what is possible and might inspire others as well.

IX. Conclusion and Outlook

This paper analyzed how inquiry-based STEM education could serve to enhance sustainable development and build capacity for future generations. It argued for an integrated and transdisciplinary approach of STEM Education for Sustainable Development (STEM4SD Education). Such an approach adds value to educating young people because it provides the fundamentals to understanding how to develop sustainability mindsets and use reflective STEM knowledge for social good.

Through the provided framework and accompanying examples from around the world, the "International Dialogue on STEM Education" (IDoS) in Berlin, December 5-6, 2019 hopes to demonstrate how educators can address the complex context of global challenges and encourage youth to draw on their STEM competence and the process of science as a key basis for reasonable action in our world. Knowledge, skills and understanding of science, technology, engineering, and math phenomena can help students understand global problems and support actions in society that address these challenges in a meaningful and knowledge-based way.

The position paper outlined a set of guiding principles of STEM4SD Education. These principles may give orientation, empower collaboration, or fuel further discussions on future-oriented education and development. The paper reflects the current state of thinking on this emergent topic, as shared among the involved experts in the international community. As the dialogue between stakeholders from science, practice and policy continues, and experience from practice growths, future adjustments may arise.

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This list is open for persons who agree with the main principles outlined in the paper and who would like to endorse the paper.

See: https://www.haus-der-kleinen-forscher.de/en/international-dialogue-on-stem-education/idos2019/position-paper/