Get Them While They're Young!:
Teaching Creative Problem Solving and Systems Thinking through Education for Sustainable Development (ESD) Approach in High School Science Curriculum

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Introduction

Employing cross-cutting solutions for sustainable development necessitates training students to foster a systems thinking mindset during their formative years. Schuler et al. (2018, p.194) characterized systems thinking as "ability to identify important elements of systems and the varied interdependency between these elements". Thus, imbibing a systems thinking mindset requires an amalgamation of a repertoire of knowledge, skills, and attitude acquired from various fields of disciplines and the application thereof in varied and varying contexts. The very nature of sustainable development – being the intersection between environmental, economical, and social development – echoes this call for inter- and even transdisciplinarity.

Given the traditional recognized boundaries in some educational systems, however, opens the question on which discipline facilitates such fundamental facet of education (Venkataram 2009, p.8). Science educators, for one, concern themselves with designing curriculua which do not end up as an isolated knowledge (van Eijck and Roth 2007, p.2765). In many cases, while learning opportunities in various disciplines present link to real-world applications, they are limited in showing that the real-world links back not only to that field of discipline, but an array of disciplines. Case in point, in the Philippines, the most recent national science curriculum aspires that students in junior high schools (grade 7 to 10) to "apply science inquiry skills in addressing real-world problems through scientific investigations" (DepEd 2016). Early attempts on communicating and concretizing this key level standard appears to be focused on pressing real-world problems, but considers a problem within a vacuum in that the system is isolated from the environment in which the learner learns and lives.

We see this gap in the formulation of curriculum on the macro-scale and its eventual embodiment on the school-level as an impetus to enrich the state-promulgated grade-level science curriculum by applying the Education for Sustainable Development (ESD) approach, in order to train young learners systems thinking and creative problem solving. After all, some of the core competencies of ESD are systems thinking and collaborative decision-making (Leicht, Heiss, and Byun 2018, p.10). With this curriculum design, technical content is decentered and is replaced with pillars of sustainable development. Through this, young learners are oriented in solving real-life problems in their respective communities not only with sound scientific grounding, but with a thorough consideration of the environmental, social, and economic implications.

As an articulation of Target 4.7 of SDG4, ESD is a brand of education that seeks to redesign curricula and realign competences such that students are prepared to respond to building a more sustainable, just, and inclusive society (UNESCO 2017). Finding its origin in recognized socioeconomic and political forums, the vision of ESD emerges from the call for education that tackles the growing environmental challenges in the past decades. However, with great anchorage to the definition of sustainable development by the Brundtland Commission (WCED 1987), ESD thus extends to considering socioeconomic dimensions of development and promotes a thinking that allows the present needs to be met without sacrificing the needs of the future. By integrating the three pillars of sustainability with culture, ESD thus is expected to develop a way of thinking and decision-making that puts the improvement of "quality of life both locally and globally on terms which are most relevant to [individuals'] daily lives" at the pedestal (United Nations, "About ESD"). As such, even though branching from SDG4, ESD is perceived as essential in achieving the other SDGs (Leicht, Combes, Byun, Agbedahin, "From Agenda 21 to Target 4.7", pp.25-26).

Various studies have identified impacts of utilizing ESD in school curricula. While critics of ESD argue that education is reduced as mere utility for championing sustainability ideals (Jickling 1994 in van Poeck and Vandenabeele 2011, p.541), United Nations has been clear in the two-fold component of ESD being education enriching sustainable development and sustainable development enriching education (Leicht, Heiss, and Byun 2018, p.10).

As such, in the process, ESD should have clear implications on pedagogy and learning. Joining several movements in education, ESD has promoted the shift from classroom teaching to experiential and participative learning. With this, there is a more critical review of the teachings being propagated (O'Donoghue, Taylor, and Venter 2018, pp.114-119) from several case studies worldwide. Beyond propagating knowledge, studies in ESD has also shown its ability to improve what are regarded as soft skills. ESD has opened underexplored opportunities for students to collaborate and innovate (McNaughton 2012 in Villanen 2014, p.180). Moreover, practice of ESD has generated compelling evidences for "sensibilization and conscientization" to various issues being faced by communities (van Eijck and Roth 2007, p.2768).

A recurring opinion on ESD calls for a complete national curriculum transformation instead of mere integration (Wals and Corcoran 2006 in Venkataram 2009, pp.8-9). While this has been proposed and done in many cases (US Partnership, "Partnership for Education for Sustainability"), we argue that countries posit different priorities during major curricular revisions depending on their sociopolitical and cultural contexts at a given time. This is supported by the fact that there continues to be a discrepancy on the understanding and thus implementation of ESD, especially among developed and developing nations, even at the end of Decade for Education for Sustainable Development in 2014. In fact, the number of case studies available from developing countries has been noted by Nguyen (2018, pp.342-343). Case in point, the growing financial challenges in the Philippines served as an impetus to transition from a college mindset to one that allows employability after senior high school in the recent K+12 adjustments.

Having said that, we concede however that such pressing needs should not banish ESD altogether from the field of education. As such, given such uneasy conditions, we propose the implementation of ESD in the Science curriculum without claiming that the field holds monopoly of promulgating what the ESD stands for. Given the uncertainty for learners to step into universities given the K+12 transition in the Philippines, we further argue that the brand of thinking ESD fosters must begin at a strategically chosen academic age of students, which considers emotional maturity and exposure to an array of academic and sociocultural experiences. With that in mind, we contend that such ESD approach is best introduced at the terminal year of uniform basic education curriculum, which is grade 10, before students enlist themselves in different academic strands and tracks. Some studies introduced ESD and systems thinking mindset in younger students (see Roychoudhurt, Shepardson, Hirsch, Niyogi, Mehta, and Top, 2017, p.73)

This paper presents a pedagogical innovation on the conceptualization, implementation, and evaluation of the Grade 10 Science curriculum, which utilizes the Education for Sustainable Development (ESD) approach, of the Ateneo de Manila High School. Throughout the four cycles of implementation, ESD is integrated through action-oriented learning pedagogy which has the following stages drawn from Kolb's learning cycle: (i) undergoing a concrete experience, (ii) observation and reflection, (iii) formation of abstract concepts for generalization, and (iv) application in new situations (Kolb, 1984 in Rieckmann, "Learning to transform the world", p.49). Ultimately, this curriculum posits itself as a response to greater role of training students in fostering systems thinking and creative problem solving.

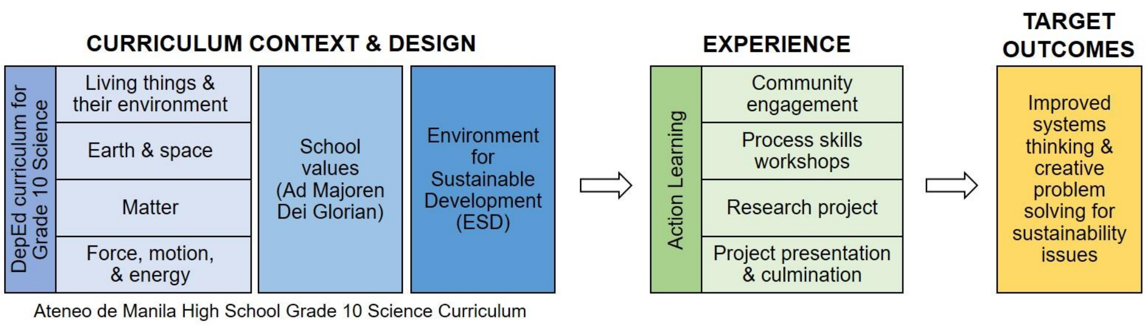

Figure 1. Roadmap to improved systems thinking and creative problem solving in this study.

Aside from detailing the pedagogical innovation derived from ESD, by gathering inputs from science teachers who have implemented the program and to the selected students who underwent the program, this paper explored three main questions qualitative in nature:

1. What are the pedagogical implications of integrating ESD in the science curriculum and the school core values?
2. What are the emerging insights of adopting action learning pedagogy in integrating ESD in the science curriculum?
3. How did the students perceive creative problem solving and systems thinking in an ESD-integrated science class?

Conceptual Framework

UNESCO has set Education for Sustainable Development (ESD) in a broad context and in a variety of issues (Venkataram 2009, p.8). We argue that this provides the education community the flexibility when translating ESD into practice. The extant literature documents that the variation of ESD models is influenced by different national contexts (Nguyen 2018, p. 342) which have resulted to curricular designs and teaching practices that deviate from what has been proposed by UNESCO (Nguyen 2018, p.353). Instead of the national context, the ESD model in this study was conceptually framed based on the school context while remained consistent with the UNESCO proposal. The conceptual framework is presented in a diagram format in Figure 2.

Many scholars are concerned with deciding what subject matter to include in the curriculum and that this decision usually relies on social needs and ethos (Christou 2013, p.259). In our case, our ESD model is primarily anchored on the school core values because we too believe that school values can be revealed in school practices and traditions (Nikkanen and Westerlund 2017, p.116). Thus, we see to it that the curricular design expresses the school core values. Many of the values the Ateneo de Manila High School aims to instill in their students resonate in the motto *ad majorem Dei gloriam* (for the Greater glory of God). The school, through its website, articulates this motto.

> *"The Jesuit expression "ad majorem Dei gloriam" gives general direction to the universal mission of the Society. This however needs to be unpacked and contextualized in an Ateneo that finds itself missioned by the Society to be at the crossroads of Church and world, faith and justice, development and poverty, and other such polar realities that mark our world today.*
>
> *"The strategic area of identity and mission seeks to describe who we are and what we are about. As we define our institutional character as the Ateneo de Manila, our specificity (or uniqueness or brand) may not always be that readily visible. In our choice of programs or in the way we teach our courses or do academic research or engage ourselves in social/national outreach, we may discover commonality with many of the outstanding schools in the world."*
> (Ateneo de Manila University, Philippines)

Bearing this articulation in mind, the curriculum which includes the academic content, instructions, activities, and assessments is designed where the school values are best operationalized.

We see a great alignment between the Ateneo school values, the expression *ad majorem Dei gloriam*, and the principles of the ESD. To us, a curriculum embedded with the purpose and the approach of ESD is an expression of the school values and a way of unpacking them. With the ESD approach integrated in the Grade 10 science curriculum, the academic activities and lessons have been enriched with content about sustainable development. Sustainable development is a universal call by the United Nations articulated in its Global Goals, also called Sustainable Development Goals (UNDP 2020).

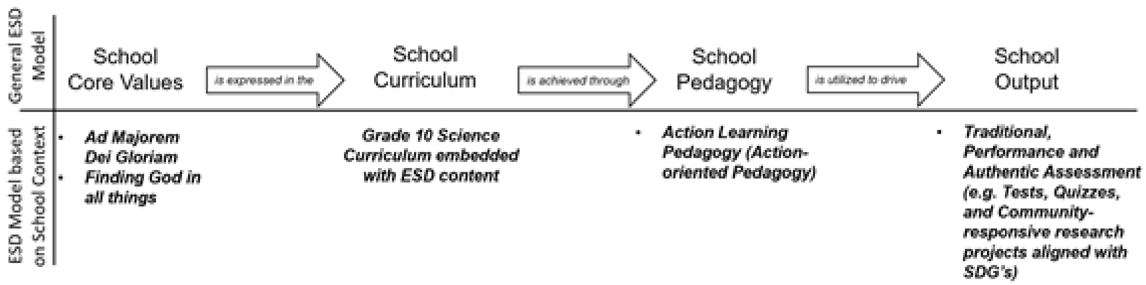

Figure 2. Conceptual framework diagram of the ESD model.

We see that the school curriculum can be best achieved through action learning pedagogy, sometimes referred to as action-oriented pedagogy. Aside from its ease to align with other learning approaches (Marquardt and Waddill 2004 in Christiansen, Prescott, and Ball 2014, p.244), action learning pedagogy fits with what ESD is trying to achieve. In action learning, "learning occurs as members construct meanings around their surroundings to help them generate new action patterns" which involves "integrating complex problems to provide opportunities for members to engage in dialogue, feedback, and reflection as a collaborative inquiry" (Werstch 1997 and Marquadt 2011 in Yeo and Marquadt 2015, p.86).

It is still possible to conduct traditional summative form of assessment when assessing students' learning in the ESD framework (Michalos, Creech, McDonald, and Kahlke 2011, p.394). Traditional form of classroom assessment includes paper-and-pencil tests and quizzes (Taylor and Watson 2000, p.19). Considering the principle of action learning pedagogy, we implement performance assessment which has been designed as authentic as possible by requiring students to locally address global issues (Newman, Brandt, and Wiggins 1998, p.20). These global issues are mentioned in the SDG of the United Nations (UNDP 2020). In short, in our ESD model, while we still assess students using traditional methods, one of the performative and authentic assessments we conduct is that students are expected to produce scientific research that supports at least one SDG.

Curriculum Design

One of the key methods in ESD identified by Rieckmann ("Learning to transform the world", p.50) was community-based research projects. While this was a central and recursive method to the pedagogical innovation we designed, our curriculum design employs other identified methods such as collaborative real-world projects, vision-building exercise such as scenario analyses, and critical and reflective thinking.

SDG Orientation

Key sustainability precepts were discussed to the students on the very onset of the school year. A standard presentation was prepared and a summary brochure was provided to introduce the students to the different SDGs. The session began by an introspection on what students associate with the word 'sustainability', as well as identification of problems they noted to persist in their local communities. Inputs from the teachers focused on understanding the definition and pillars of sustainability, the Sustainable Development Goals, and a priming on the state of global and national affairs which suggests the need for the SDGs.

The previously described composition of the orientation served as the springboard for the discussion of the theme for the year-long science research project component of the class, which was “*Ad Majorem Dei Gloriam* for Sustainable Development Goals” (AMDG for SDG), alluding to the school’s values. During this portion, the mechanics on the standard science research project, which can be investigative or inventive in nature, required for the Grade 10 students were described. In certain iterations, graduate students of the university were invited in a science research symposium and networking entitled “Sciences for Sustainable Communities” where they shared their on-going researches contributing to several of the SDGs.

Scientific Process Skills Workshops
Central to the curriculum are the workshops on scientific process skills and follow-up consultations which guide the learners on developing a community-based scientific research project addressing their chosen SDGs. As a tool envisioned to have a transformative effect of students as individuals, ESD necessitates teaching and learning methods that engage and empower the students to orient them towards action (Leicht et al., “From Agenda 21 to Target 4.7”, p.35). The workshops began with introduction of the topic and essential tips and followed by group discussions. Worksheets were provided to students to guide their discussions. Fulfillment of worksheet extends beyond the session to allot time to do library work whenever necessary.

The workshops during the first academic term were on identifying the problem and focusing the study. While students were previously asked of a pressing need of their community, a good portion of the students opted to address a need they witnessed in the community they visited and stayed with for the weekend as part of their Grade 10 service learning program and socio-civic outreach. Also, some used the visit to university sustainability facilities, such as the materials recovery facility (MRF) as inspiration to their project. The workshops during the second academic term were on drafting their methodology that satisfies the objectives and beginning with experimentation and/or deployment while the workshops on the third term focused on analyzing data and presenting effectively to target audience. Beyond the workshops, consultations were held to probe into the status and action plans of the individual groups. Consultations were a good avenue also to allow the groups to introspect how their study relates to their other academic classes. Ultimately, the goal of the workshops and consultations was to facilitate the conduct of the year-long research study on their defined problem.

Integration to National Curriculum
As the revised K+12 curriculum employs a spiral approach where selected concepts from each of the four domains (Living things and their environment; Earth & space; Matter; Force, motion & energy) were covered from grades 7 to 10. The curriculum employs various teaching strategies such as seamless integration of sustainability precepts in topic discussions, activities such as debates and case studies, and plenary lecture and processing. Table 1 below lists some integration points utilized in the classes:

Table 1. Integration points of sustainability precepts in the national K+12 curriculum.

Domain	**K+12 Curriculum Strand (particular topic)**	**Integration**	**Activities Conducted**
Living things and their environment	Biodiversity and Evolution (variation, speciation)	Conservation issues worldwide Challenges in conservation in the Philippines	Film viewing (“Racing Extinction” / “Chasing Ice”)

	Biodiversity and Evolution (energy flow)	Waste audit in the university	Visit to the university materials recovery facility (MRF) and vermicomposting
Earth & space	Geology (earthquakes)	What to do before, during, and after an earthquake	School-wide emergency drills (in partnership with the High School Disaster Risk Reduction Committee, Reserved Officers Training Corps, and Quezon City Disaster Risk Reduction and Management Office)
Matter	Properties and Structure of Matter (gas laws)	Greenhouse gases	COP21 “UN model”
Force, motion & energy	Energy (electricity)	Alternative sources of energy	Debates on appropriateness in the Philippine context

The table above is not in any way exhaustive, as strategies were adapted to the context of the class and the perceived need by the teachers. In one iteration, a plenary talk was given by our University President, who is a member of the Intergovernmental Panel on Climate Change which won a Nobel Peace Prize for their study on carbon emissions. Additionally, integration of some topics was extended beyond the Science classes. For example, coordination was done with the school’s Disaster Response Committee to perform the briefing on science behind earthquakes, the appropriate responses, and effects to communities. Evaluation of the approach was done after every cycle, and revisions were made in the succeeding cycle.

Culminating Activity

As part of the approach, all groups presented their study in front of the class with invited panelists from different disciplines. While the groups learn primarily contextually from their own experience and their own project as noted in similar studies (van Eijck and Roth 2007, p.2766), the culminating activity allows them to learn from others’ findings and experiences.

After a class-level round of presentation, a selection process identified the class representatives who presented their outputs to the school. Highlighting the value of effective scientific communication, each cycle culminates with a project presentation through a science congress reiterating the theme “Ad Majorem Dei Gloriam for Sustainable Development Goals” (AMDG for SDG). Aside from the day-long congress, peripherals in campus were set to promote the theme.

Sample Student Outputs

While Rieckman (“Key themes in education for sustainable development”) identified key aspects of ESD (namely climate change, biodiversity, global justice, disaster risk reduction, sustainable production and consumption, reduction of poverty), this framework allowed groups to choose the SDGs they want to tackle. Students were invited to tackle several SDGs as inter- and transdisciplinarity highlight the existence of these goals not in isolation.

Table 2. Selected research outputs of students.

Academic Year	Research Title	Target SDGs
2015 – 2016	Intracellular biodiesel production and lipid content characterization of microalgae isolated from local water environs in the Ateneo de Manila University	7, 14
	Evaluating the potential of *Pterygoplichthys disjunctivus* Weber (janitor fish) skin as an alternative: a community-based initiative for the benefit of the shoe industry in Marikina	8, 9, 11, 12
2016 – 2017	Harnessing small-scale electrical energy from a mechanically-enabled direct current (DC) USB generator to power mobile devices	7, 12
	The utilization of *Eichhornia crassipes* (water hyacinth) as a component for coffee cup insulators	12, 14
	Determining the effects of varied environmental conditions on the potency of tetanus toxoid vaccine: a baseline for designing a sustainable passive container system in transporting vaccines in rural areas	3, 9, 11
	A comparative study of the efficacy of *Tenebrio molitor* larvae and *Zophobas morio* larvae as degradation agents of expanded polystyrene foam	12, 13
	Use of leap motion sensor to identify and translate 15 letters of the American Sign Language (ASL) alphabet	4, 10
2017 – 2018	Exploring the effects of selected perennial plants in the Philippines in reducing the level of lead in soil	2, 12, 15,
	The utilization of recycled materials in the production of electromagnetic amplifiers	7, 12
	The feasibility of *Moringa oleifera* (malunggay) seeds as filter for stagnant water	3, 6
	Development of a sustainable agricultural procedure through the infusion of vertical farming and a drip irrigation system	2, 6, 15
	The use of *Hordeum vulgare* L. (barley) and *Triticum aestivum* (common wheat) to create edible and biodegradable utensils	9, 12
2018 – 2019	Integrating rice hull ashes (RHA) in concrete brick production: opportunities for constructing sustainable sidewalk pavements	9, 11, 12
	Potentials and challenges of creating a three-dimensional photogrammetry model of a structural unit	9, 11
	The use of a peltier tile in the design and construction of a portable refrigerator for vaccines	3, 9, 11
	Characterization and evaluation of *Cycas revolute* (sago) starch bioplastic as edible substitute to polypropylene straw	11, 12, 13
	Utilization of *Eucheuma denticulatum* (guso) and *Caulerpa lentillifera* (lato) as main components of bioplastics	12, 13

This approach recognizes a greater diversity in topics could be covered when the ESD approach developed here is applied on the institution level.

Implementation Feedback and Outcomes

In order to explore the pedagogical implications of the AMDG for SDG program, we have conducted an online focus group discussion, using Google Meet, to three (3) science teachers who have implemented the program excluding ourselves. As a full disclosure, we were part of the Grade 10 level team that has implemented the ESD integration in its science program. The three participants have backgrounds in science education; having different length of years in teaching science in the Ateneo de Manila High School: 25 years, 15 years, and 5 years. We asked about their perceptions on the impacts of ESD integration in their personal and organizational pedagogical practices, as well as their perceptions on action learning and their overall assessment on the effectiveness of its effectiveness in integrating sustainable development in the curriculum.

Aside from the teachers' perspectives, we also explored the experiences and insights of the students who underwent the ESD program. We conducted an online focus group discussion to selected students, particularly focusing on their perceptions on how they were able to manifest creative problem solving and systems thinking in completing their research projects.

On Pedagogical Implications

In this paper, we argue that the integration of ESD in the curriculum has corresponding pedagogical implications in terms of the Ateneo de Manila High School's science program and school core values. This conforms to the argument of Venkataraman (2009) that integrating sustainable development in an existing curriculum framework would require certain adjustments in the educational proceedings. We define educational proceedings as anything that pertains to curriculum development, instructional planning, and classroom instructions – these serve as our criteria on the impacts of ESD integration in the science curriculum.

The FGD began with a mind-mapping activity which aims to elicit ideas that they associate with ESD. Using Jamboard, an interactive online blackboard, the teachers posted their ideas which can be seen on Fig. 3. Each participant was then invited to expound their posted idea. Their ideas were then processed and analyzed.

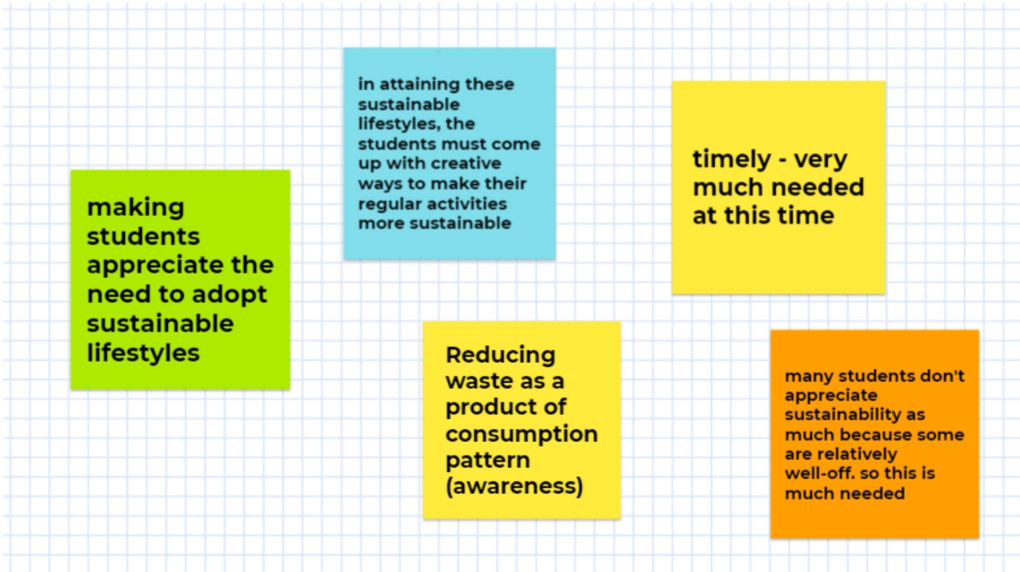

Figure 3. Jamboard screenshot of the online mind-mapping activity.

In order to highlight the pedagogical implications of ESD, which is the focus of the first research question, we processed all feedback and input by applying a deductive approach where we initially identified two general themes based on Venkataraman's (2009) framework on sustainability education. These themes include: Development of the Science Curriculum and Classroom Teaching Preparations.

Development of the Science Curriculum

During the summer in-service sessions in the Ateneo de Manila High School, faculty members were given the chance to revisit and improve their existing curriculum. This served as an opportunity to integrate points-for-improvements that were identified during the previous school year. During the FGD, the participants highlighted how their science-related educational background influence their decision-making in crafting the science curriculum.

Alignments of science curriculum to SDGs were initiated by science teachers and the instructional planning was heavily influenced by their respective backgrounds. As such, some teachers expressed as a reflection on their experiences the more science-focused SDGs were highlighted more than those referring to peace building, gender inclusivity, and social justice. During the FGD, the participants highlighted these responses:

A teacher from the earliest iteration noted that ESD implemented was still in its infancy and integration was done whenever possible. However, in the recent iterations, a more inclusive promotion of SDGs were made due to a more streamlined collaboration between the Science and the Social Sciences subject areas. Students find this cross-cutting approach as a sign that sustainability is not only confined to the field of science but can encompass other fields such as the social sciences and humanities.

Classroom Teaching Preparations

The participants also highlighted how ESD integration made an impact on their classroom teaching preparations. It has highlighted that at one point in their teaching preparations, they had to be conscious on how they will design their classroom activities, such that they require unnecessary wastage of resources. It was also highlighted how their usual lab and other engaging activities need to use sustainable materials – emphasizing how they shifted from conventional materials to a more sustainable material. One of the most common sustainable classroom practice that they have adopted was the reusage of one-sided (recycled) A4 papers for printed requirements, instead of throwing them away. Some of their responses during the FGD include:

Furthermore, the participants reflect on the essence of sustainability to their students as a process, and not just a mere concept or theory. One of the participants recalled a particular incident seeing his students finishing a big soda bottle to fulfill a requirement of bringing a recycled/used plastic bottle for an innovative lab activity. This incident just defeated the purpose of the kind of sustainability valuing that they wish to inculcate to their students. But still, continuing with the program was worth it since the student get the chance to understand and clarify their concerns on how to become more sustainable in their lifestyle.

Emerging Insight about Action Learning Pedagogy in ESD

The second research question highlights how action learning pedagogy aids in the promotion of ESD in science curriculum. In exploring this question, the FGD questions emphasized how the science research projects of the Grade 10 students under the AMDG for SDG (*ad majorem Dei gloriam* for SDG) program conforms to the action learning pedagogy.

In a seminal report on trends in ESD, Leicht, Heiss, and Byun (2018, p.10) claims that ESD necessitates an action-oriented pedagogy. As mentioned, action-oriented learning pedagogy considers these four elements, namely (i) undergoing a concrete experience, (ii) observation and reflection, (iii) formation of abstract concepts for generalization, and (iv) application in new situations. We thus also explored the perceptions of the teachers and students in line with the adoption of action learning pedagogy as a framework in ESD integration. From their responses, three (3) overarching insights emerged: 1) Students' selection of research topic, 2) Research project as action learning, 3) Recognizing sustainability in various context.

Students' selection of research topic

With the exposure to the AMDG for SDG theme, the teachers noted that the students were more conscious in selecting their research topic. Through the action-oriented learning pedagogy, the learners experienced firsthand doing scientific inquiries and investigations on a problem they recognize from their own communities using observation and experience. Some students identified indigenous practices that they wish to verify using scientific approaches. Students refrain from science research topics commonly found online, because they are asked to address a problem in their community. As such, the commonly found topics online do not necessarily satisfy the contextualized concerns of the society.

Furthermore, some students identified that recent events during the time of conception of the project (i.e., natural hazards such as earthquakes, infrastructure collapse) prompted them to contribute a possible solution to the matter. Insights from friends' experiences and inputs from science teachers from years prior also contributed.

Research project as action learning

Teachers opined that the research project is the most suitable way to perform action learning pedagogy. Some students opined that, aside from the class lectures, "the research project provided insights on how sustainable development and systems thinking can be observed in daily life.”

The array of learning experiences we designed in our approach satisfy the elements of action-oriented transformative pedagogy, namely “self-directed learning, participation and collaboration, problem-orientation, and inter and transdisciplinarity, as well as the linking of formal and informal learning” (Rieckmann, “Learning to transform the world”, 40).

Recognizing sustainability in various context

Through the experiences they underwent, students also have a growing embodiment of recognizing sustainability in various contexts outside their science class. Students in the senior high school (pre-university) who went through the curriculum were noted by their teachers to have posts about sustainability on social media showing the concepts they learned from grade 10. There was in fact a student-led school project where they sold sustainable merchandise to fund community outreach projects.

This paper echoes van Eijck and Roth (2007, p.2768) on their claim that their ESD curriculum did not only propagate scientific knowledge which may be forgotten after a school term, but directs participation in changing the society.

On Perceptions about Creative Problem Solving and Systems Thinking

We asked them about their perceptions on sustainable development – the most recurring idea is eco-friendly mindset, not being wasteful, and utilization of wastes. Figure 4 shows a screenshot of the interactive board.

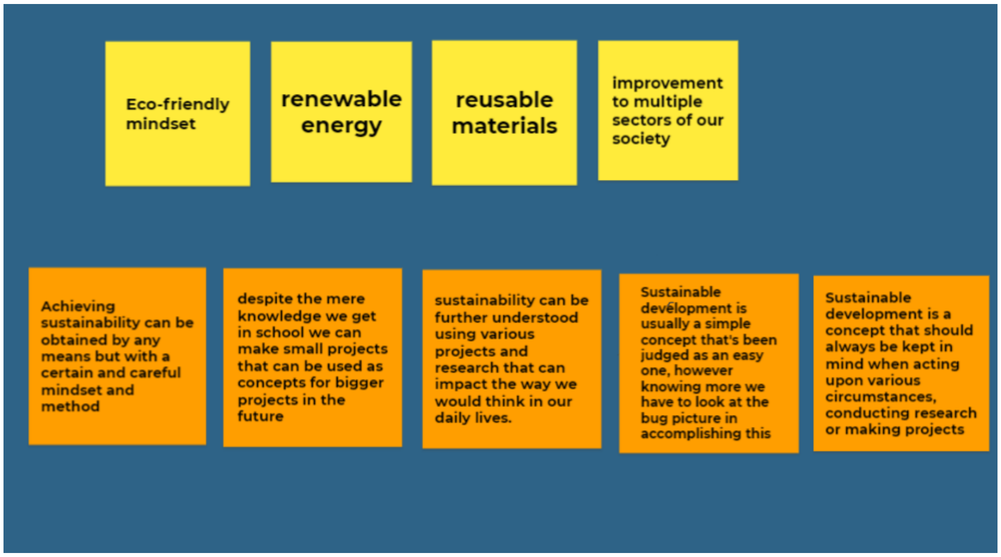

Figure 4. Jamboard screenshot of the students’ online mind-mapping activity.

From the online FGD with students, we explored their experiences and input which led to the general recurring idea that systems thinking promotes creative sustainable solutions. Much of what they have shared highlights the processes they underwent in completing their research projects.

In conceptualizing their research topic, the students have considered to tackling the gaps in social structures and to contribute to the vulnerable sectors in the society, wanting to reduce plastic production, inspiring others with how to use indigenous knowledge. These responses highlight how they prompt their creativity in finding inspiration for their topic. In line with this, while some groups conducted their tests in research centers, some students noted the home-based experimentation they performed could be improved by doing in a more appropriate testing center and with the supervision of a professional.

We also asked their insights about systems thinking and how they applied it in their research projects. They also believed that systems thinking is a holistic mindset to achieving sustainable practices as highlighted in the statement below:

> *Student A: Achieving sustainability can be obtained by any means but with a certain and careful mindset and method. Despite the mere knowledge we get in school, we can make small projects that can be used as concepts for bigger projects in the future.*
>
> *Student B: "Sustainability can be best understood with systems thinking because it makes us ponder how to make innovations that cannot be destructive to future generations… How one action can affect other sectors. It may be effective to answer a research question, but not effective and be destructive to another sector."*
>
> *Student C: "Sustainable development is usually a simple concept that's been judged as an easy one, however knowing more we have to look at the big picture in accomplishing this."*

Systems thinking is one of the widely recognized key competences of ESD (Schuler et al., 2018, p.192). It was affirmed by the group that sustainability can be best understood with systems thinking because it made them ponder on how to make innovations that are not destructive to future generations. This idea conforms to the main theme of sustainable development – responsible use of resources for the welfare of the future generations.

Future Directions

This study is expected to serve as a benchmark on how the ESD can be mainstreamed through integration to the Science curriculum of a secondary school in a developing country, which has limited literature on ESD. Currently, the workshop handouts, presentations, rubrics and metrics, and sample outputs are deposited in a repository for potential dissemination to science educators in the country through teachers' training initiatives in the future. Ultimately, the approach intends to cultivate a community of learners who demonstrate scientific innovativeness and systems thinking, as well as empathy and sustainability mindset directed to the common good.

Given that the infancy stages of this approach focuses on adjusting pedagogy and promoting systems thinking to students, moving forward, more integration points can be explored especially on areas on goals not emphasized. For one, following online trends, the curriculum could include several sessions of women in science. Additionally, more school-wide reinforcement of sustainability practices in the academics (i.e., inter-subject integration) and school infrastructure (i.e., wastewater treatment, LED lights) would serve as a greater articulation of embodiment of sustainable development at the school level. Activities of other subject areas, while imbibing rather noble objectives, might be perceived by students as wastage of resources.

While this paper reports impacts on educators and learners after a cycle of ESD curriculum in grade 10, conducting an evaluation of lasting impacts of the curriculum at certain number of years post-participation can produce interesting insights. Moreover, the scheme can revisit the idea on what happens after the year-long iterations. The outputs, especially those with invention-type mock-ups, need follow up. The institution may create a system to connect the students' output to the national science and inventions board through the information technology management and intellectual property offices of the university.

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