A Measurement Instrument to Assess Engineering Student´s Knowledge about Sustainable Development

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Abstract– The purpose of this paper is to present a measurement instrument to evaluate the knowledge that engineering students have about sustainable development (SD) aspects. Sustainable development is a topic of upmost importance at the present, given the situation that our society is facing regarding the deterioration of our planet. This is mainly due to bad practices related to the way human beings have been using the resources the earth offers. The comprehension of the connection between our actions and the evolution of our planet are clearer now than before. The harmful effects of heat waves, draught, heavy rains, are among the phenomenon that tell us the earth is changing. In this sense, this study adopts a measurement instrument previously designed, to measure the understanding about SD among engineering students of Universidad Tecnológica de Panamá. The questionnaire was reviewed to adapt it to the reality of engineering students in Panama. The objective of the study is to present a measurement instrument capable of evaluating the understanding the students have about SD. A careful review of the literature was conducted to provide a good basis to confirm the main aspects that need to be incorporated into the question items. Four main aspects are proposed: environmental, economy, societal and educational aspects. Environmental aspects and SD are directly related, any development that humankind sets to accomplish has an impact on the environment and therefore on the sustainability of the world. Economy aspects are also strongly related to SD, the elimination of income inequalities, the empowerment of women, the promotion of youth employment and decent work for everyone are key objectives of SD. The full participation of the citizens in the economic system of every nation is a requirement of the agenda of SD. The societal dimension considers that every person has the responsibility as part of the society, to take action and protect the planet we live in. The new generations should be more aware of the role they could play as members of their community, solving problems and communicating effectively to make positive transformations. Finally, the educational aspects Students should acquire the competences that empower them to be proactive towards finding solutions for the environmental problems. The main purpose of education for SD should be to empower the students to be active in society and make changes that contribute to SD. In this regard, the teaching methodology should always set clear goals to accomplish students´ understanding of sustainable issues.
Keywords—Sustainable development, Education for Sustainable Development, Environment, Economy, Society.

I. INTRODUCTION

Sustainable development (SD) is defined as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" [1].

Education for sustainable development (ESD) aims at promoting "values, behaviors, and lifestyles that are needed to restructure society and find solutions to global economic, social, and environmental challenges." [2], [3]. According to the United Nations Agenda 2030, the objectives of SD are defined in terms of key factors that need to be addressed and taken into account for decision making at all levels, public and private sectors, to preserve our planet [3].

In order to accomplish the objectives of SD, the universities have the key role to create knowledge and transfer it to society. In this regard, the students are the actors in charge of disseminating the information that can transform the society to adopt SD practices in personal and professional activities of every member of a community. The knowledge of the student about SD definition and practices is crucial in achieving the SD objectives [4]. Education at all levels is responsible for raising awareness; if the educational system remains the same, no effort towards a more sustainable world will produce the desire results, in terms of a greener planet and better quality of life for everyone.

The purpose of this research is to design a measurement instrument to evaluate the knowledge of university students about SD. If it is possible to evaluate this level of knowledge, then it will be possible to reinforce those aspects that are least known by the student, so that he/she can become the agent of change that the society needs to disseminate the right information, generate knowledge in society and foster SD practices in the community. The incorporation of SD theory and practices in the teaching material is imperative so that the students acquire the information and tools they need to address the needs of the society. This is especially true in institutions whose programs are mainly engineering degrees, which is the case of Universidad Tecnológica de Panamá, where this research is conducted.

Following previous research, we also believe that every human being should be part of the solution to build a better future [19] for present generations and for those to come. Every country needs to be aware of national realities that mainly refer to levels of development, capacities and priorities; these should define the manner in which each nation will incorporate changes to achieve the objectives of SD. Government policies and strategies should be decided and implemented in accordance with the circumstances of the nation.

II. LITERATURE REVIEW

In order to successfully incorporate SD actions in society, it is imperative that the institutions of higher education play a key role through education of the students. According to Reference [5], the technological aspects and nontechnological aspects are equally important. There has been a strong emphasis on technological aspects to develop SD practices or operations that make waste management more efficient, clean water available to everyone, technologically advanced waste collection vehicles, effective wastewater treatment, among other advancements. The non-technological aspects, however, have not received the same degree of attention.

Reference [6] found that the main obstacles for successfully implementing sustainable development actions in universities are related to non-technological issues such as weak management support, lack of availability of the right infrastructure, poor awareness about sustainable development issues among the community, absence of environmental committee, few green building constructions and weak government support.

Some authors have identified the main aspects for an effective participation of universities in activities directly related to sustainable development [7], [11]. Through focus groups and interviews with experts, they found that the creation of university campus garden, regular meetings for campus sustainability ideas generation, online conferences, forums and events for the promotion and learning of sustainable development among university members are important aspects to develop sustainability in higher education institutions. Other actions under consideration by the experts were the establishment of taxes for sustainable development actions. The participation of members from different sectors of the university, for instance professors, administrative staff and students, demonstrated to be a critical factor for the success of sustainable practices [2], [4], [6], [7]. It is only through the integration of everyone, working together for the common purpose of achieving the SD goals that our world will be a better place.

The identification of critical aspects for effective participation in achieving SD goals at university level results in three main areas that need to be studied: environment, economy and society. In addition to these, latest research points out to the need to incorporate education as an important area of research, due to the necessity to include SD information in the curricula and build knowledge among the new generations [8], [9], [12]. There is a definite connection among environment, economy, society and education. The holistic approach to SD states three main aspects: 1) the environment, economy and society interrelationship; 2) time dimension, identified as past, present and future SD implications; and 3) space dimension, identified as local, regional and global aspects [17], [18].

The pluralistic approach to SD, on the other side, refers to teaching strategies and learning methodologies. This approach states that the active interaction between teacher and students is essential to establish conditions in which information flows and knowledge is generated among the new generations [13], [14], [17]. It requires student centered teaching methods, participatory decision making at all levels of society, government, private sector and civil society in general.

A. Environmental Perspective

Many studies recognized this perspective as the most important in SD, this is because of the clear connection between our daily life and the natural environment. At present time, any economic or social development that humankind sets to accomplish has an impact on the environment.

The deterioration of our environment and climate change are main problems that need to be tackled by each one of us. The magnitude of the problem requires for every nation to cooperate designing regulations, approving laws and promoting habits that help reduce and prevent degradation of our planet´s natural resources. The conservation and responsible use of oceans, seas and rivers as well as the protection of forests, ecosystems and biodiversity should be every government´s priority. There are also issues that we need to resolve mainly because they already affect many people, among these are water pollution, desertification, land destruction and drought [3], [11], [12], [19].

Urban development must be well planned to minimize the impact on natural resources. At the same time, the utilization of chemicals which pose risks to humans and animal´s health must be eliminated [20], [22], [24]. Alternative mechanisms that provide clean solutions to our needs must be designed.

Several authors state that finding efficient ways to produce energy with the purpose of reducing carbon emissions is imperative [20], [21]. In this same line of thought, raising the quality of the environment is necessary to provide proper quality living standards for our communities. Reference [20] studied the effect of innovation, renewable energy and economic growth on carbon emissions and ecological footprints for six ASEAN countries. They found that economic growth translates into higher carbon emissions. At the same time, they found that ecological innovations help reduce environmental degradation. Their study suggests that to mitigate the negative impact that economic growth has on the environment, it is necessary that countries establish environmental reforms with the main objective of reducing carbon emissions. To a great extent, economic activities depend on transportation mechanisms that are based on traditional energy sources, thus the incorporation of equipment and machines that are energy efficient and use renewable energy sources represent the best option.

Through a study of 15 renewable energy-consuming nations, reference [22] found a positive impact between renewable energy utilization and economic growth. Renewable energy production, however, poses threats in different ways such as: alterations of land use due to, for instance generation of bioenergy or hydroelectric reservoirs and destruction or deterioration of ecosystems due to wind power generation. It is important to recognize the impact that

the different sources of energy have on the environment and promote the use of those that minimize environmental degradation.

The connections between natural resources, technological innovations, economic growth and the ecological footprint are strong. While economic growth has a negative impact on the ecological footprint, the right technological innovations have a positive impact reducing environmental degradation [23]. A study conducted in the UK [24] explored the integration of energy storage, heat generated with wind turbines, solar panels and non-renewable energy. A simulation tool was developed and proved to be able to supply approximately 63% of the heat demand per year and reduce carbon emissions by approximately 60% per year.

Another important aspect is water system management given the increasing demand of urban water. It is necessary to design forecasting tools capable of analyzing the dynamics of this demand [19], [25], [26]. It is well understood that the connection between water and energy is strong, for energy generation we need water, similarly, the extraction, treatment and distribution of water requires energy. Also, the utilization of energy produces carbon emissions that need to be controlled. As the world population increases, wastewater treatment processes also become more intensive. Wastewater treatment plants require energy, a UN study revealed that approximately 8% of the world energy consumption was due to some kind of water treatment process [3].

B. Economic Perspective

The 2030 UN Agenda for SD establishes the importance of economic growth that is inclusive, sustained and sustainable [19]. Every country needs to nurture economies that are centered around its people; this can be achieved through the sharing of wealth among all citizens, the elimination of income inequalities, and the empowerment of women. Youth employment and decent work for everyone must also be established as priorities of every nation. The full participation of the people in the economic system, trough fulfilling jobs and decent work, will strengthen the productivity capacity of the country and will increase the levels of creativity and innovation [8], [19]. These factors have a positive impact on the development of any nation.

One important aspect that affects the economic development of nations is international migration. The economic impact that migrants may have on the country of origin, transit or destination should be taken into account for sustainable development so that migrants´ inclusive policies are defined and established. In this sense, the respect for the rights of migrants, displaced persons and refugees must be strengthened [11].

Inclusive and sustainable industrialization is one goal of SD, however it poses many challenges due to the dynamics of the economic systems. Economic activities refer to any activity that individuals or organizations carry out to generate, sell or buy services and/or goods. They cause different social and environmental impacts, some are positive while some are negative [27]. Government policies that objectively take into account the different perspectives for decision making are required. The nexus among water, energy and food should be treated as they are interdependent; governmental regulations for economic activities need to consider this interdependency to avoid incoherent policy making that focuses on specific sectors only [27], [28]. Cross-sectoral institutionalization of the SD goals will eliminate trade-offs that compromise SD.

C. Societal Perspective

Every person has the responsibility as part of the society, to take action and protect the planet we live in. Ichinose [17] found that through ESD, students were more aware of the role they could play as members of their community, solving problems and communicating effectively to make positive transformations. Central to the goals of sustainable development is the responsibility of every nation to protect the rights and freedom of every human being, every person should receive respect and be entitled to fundamental rights, no matter skin color, race, language, religion, sex, political opinion, or any other form of distinction [19].

One main goal of sustainable development is for everyone to enjoy a basic standard of living including social protection systems and health care. Every state should promote physical and mental health for its citizens. It should also increase life expectancy through an efficient health system for everybody. Sex education should be provided in progressive steps so that it is responsibly handled to teach young children according to their age, at school and at home. Every society should promote the rights of its citizens, especially children and youth, so that they can fully develop into active citizens capable of making changes that transform their communities [19], [29].

Peace, security and sustainable development are interrelated. Building peaceful communities where the rights and freedom of the citizens are respected, and where there is a justice system that ensures everyone receives the benefits of transparency are key objectives of SD. Urban development must be planned so that the quality of life of the citizens is improved; it should promote the community as a group of people who help each other and work for the progress of the group.

Civil society must be informed, educated, engaged and empowered to be able to actively participate in attaining SD goals. Data and information about the status of SD indicators are not enough; communication of stories of success that help people in different sectors of society to comprehend the depth of the SD goals is required. Marginalized sectors of the community should be included in governmental policy making so that effective inclusive strategies are established [29].

D. Educational Perspective

This perspective refers to a learning environment where specific educational goals are clear, course contents necessary to achieve students´ competences are established, and teaching methodologies that motivate students to learn are followed. In

this regard, the teaching methodology should always set clear goals to accomplish students´ understanding of sustainable issues [17]. Students should acquire the competences that empower them to be proactive towards finding solutions for the environmental problems.

The main purpose of education for SD should be to empower the students to be active in society and make changes that contribute to SD. Some authors have designed a model to understand the relationships among competences, learning, intervention and assessment, four pillars necessary to activate the learning environment that stimulates students to develop better skills to promote environmental protection [13].

When referring to ESD, the learning environment should provide conditions that foster critical thinking. Previous research has pointed out two perspectives regarding teaching about SD: holistic and pluralistic perspectives [13], [14]. On one side, the holistic approach considers that ESD should be based on the past, the present and the future, at the same time, it should consider the importance of local level practices as well regional and global practices.

ESD is characterized by lessons about the environment that strengthen our commitment to its protection, that help construct a mind-set of caring for our community [17]. The educational system should promote lifelong learning opportunities available to every person; the university curricula needs to integrate SD education in every subject.

III. METHODOLOGY

This research builds upon the work developed by previous authors [8], [10], adapting a measurement instrument composed of several questions to evaluate the comprehension of undergraduate students about SD aspects and practices. In this regards, four main aspects are considered: environment, economy, society and education. This is the first stage of the research. The content of the measurement instrument is defined in Table 1.

TABLE I
RESEARCH CONSTRUCTS TO ASSESS STUDENT´S COMPREHENSION
OF SUSTAINABLE DEVELOPMENT*

Environmental Aspects
Any action of human beings that impacts the environment needs to be carefully analyzed.
There is a direct connection between protecting the environment and providing quality of life for everyone.
Protecting the environment should always be first priority when considering industrial agricultural production.
Protecting the environment is more important than construction of buildings.
When considering industrial growth, protecting the environment should be first priority.
Economy Aspects
Government economic policies should increase sustainable production even if it means spending more money.
Human beings should sacrifice more to reduce economic differences between populations.
Government economic policies should increase fair trade.

Government economic policies should act if people are wasting natural resources.
Reducing poverty and hunger in the world is more important than increasing the economic well being of the industrialized countries.
Societal Aspects
Each country can do a lot to keep the peace in the world.
The society should further promote equal opportunities for males and females.
The contact between cultures is stimulating and enriching.
The society should provide free basic health service.
The society should take responsibility for the welfare of individuals and families.
Educational Aspects
University professors should use student-centered teaching methods.
University professors should promote future-oriented thinking in addition to historical knowledge.
University professors should promote interdisciplinarity between subjects.
University professors should promote the connection between local and global issues.
University professors should promote critical thinking rather than lecturing.

*Adapted from Biasutti and Frate, 2017.

A. Design of the Study

The set of 20 question items described in Table 1 below will be applied through an online survey to engineering students of Universidad Tecnológica de Panamá. This will be a second stage of the research. As of August 2022, Universidad Tecnológica de Panamá registered a total of 27,500 students nationwide. The university has a main campus in Panama City, and regional university headquarters in every province of the country. It will initially be applied to industrial engineering students in the main campus, it will then be applied nationwide.

The question items will be evaluated using the Likert scale of five points to measure degree of acceptance among the sample selected through probabilistic sampling. The data collected will be analyzed using SPSS. The statistical analysis will focus on reliability of the scales through calculating Cronbach´s Alpha index, hypothesis testing and factor analysis. In this regard, hypothesis testing should provide statistical evidence about the significance of the questions to assess students´ perceptions about the aspects under evaluation. Factor analysis will reveal the commonality among the question items under each scale.

B. Development of the Constructs

The capability of the individual to understand the importance that the environment has on our daily life is crucial in this regard. Recognizing the importance of the environment and the connection it has with our human nature is one key aspect that needs to be considered when designing a measurement instrument of this nature. Five question items are designed to measure the knowledge and understanding the students possess about environmental issues (See Table 1).

The environmental aspects refer to the relation of human beings and the environment, the protection of the environment as a primary way of providing adequate quality of life for people, and considerations about agricultural and industrial production.

When referring to aspects related to the economy, it is necessary to analyze economic advancements that can be achieved without affecting or having a negative impact on the natural resources. This mainly relates to governmental economic policies that can be established to protect the environment. The economy aspects relate to the need for all governments to plan and implement sustainable production systems and strengthen fair trade at all stages of the production system. The reduction of economic differences among the people should be addressed through the design and implementation of policies and strategies that directly tackle problems such as hunger, poverty and extreme poverty.

The societal issues encompass the individual and the community. It takes into account that we all belong to a group and share the responsibility for the space we live in. The awareness of individual and collective needs, for present and for future generations, is at the centered of SD thinking.

Finally, education is also a key aspect to support the model of Sustainable Development and achieve its objectives. Science, technology and innovation provide the basis for high quality education for SD. The continue sharing of information with new generations will ensure that they can produce their own knowledge and impact their community towards a better and more sustainable living.

IV. CONCLUSIONS

The educational system should provide for students´ development of SD competences, specifically knowledge and skills that allow the students to gain the information they need to actively participate in defense of sustainable development. The educational system needs to teach students to think critically and be able to generate alternative solutions to solve SD problems.

This paper presents a measurement instrument composed of 20 question items designed to evaluate the understanding that university students have about the research topic. It has been adapted and modified to try to measure as best as possible the real knowledge our students have about SD. It will be first applied to engineering students, starting with industrial engineering majors which is the largest department of our university. The results will shed light on the aspects that need to be strengthened in teaching undergraduate students. In this manner, the university will be in a better position to help students acquire the skills and competences that will help them be agents of change to promote a better understanding about building a more sustainable world.

The four main aspects that relate to environment, economy, society, and education are evaluated in this paper and indicate that SD goals can be achieved if these four aspects are included as integral part of any effort to attain the goals. Every country needs to define clear policies and strategies that set the priorities to promote sustainable development.

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