# A Benchmarking Study to Build an Engineering Training Model for Enhancement of Environmental Responsibility

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**Abstract.** The socio-economic world aims to sustain its activities in the face of ecological transitions, but the dangers caused by certain shortcomings with regard to the planet in relation to environmental issues are very critical. Therefore, to achieve sustainability and face environmental challenges, it is important to train conscious and responsible decision-makers, to manage and guarantee a good sustainable development for the country. Engineers play and participate fundamentally in the evolution of the country; they must also be aware of this dangerous situation. To achieve this goal, it is an obligation to train responsible and active engineers for the future, who can give very protective and long-lasting solutions when managing the projects. Many researchers propose appropriate training models for engineers in different sectors, and in particular in sustainable development. This work aims to present the different pedagogical approaches and the existing recommendations for training programs in relation to ecological transitions. Then a Benchmarking study is carried out, to identify the most important and necessary criteria to have a responsible engineer in terms of environmental issues. These criteria will make it possible to build an educational system of optimal training program models based on a comparative study to reinforce the environmental responsibility of engineers.

**Keywords:** Training programs · Environmental issues · Benchmarking study · Model's criteria · Environmental responsibility

## 1 Introduction

The socio-economic world is under pressure to respect and preserve the ecological systems necessary for the sustainability of our planet and to keep the recommendations made by the United Nations (UN) and the Global Action Program (GAP) in focus for all project planning proposed by these agendas. In order to carry out eco-responsible projects, managers and engineers must have a spirit of sustainability and green skills. Ecological sustainability must therefore be included in the training of engineers as stated in the SDG needs of the planet and these goals to keep the wheel stable towards sustainability, which is stated in the Sustainable Development Goal 4 (SDG 4). The adaptability


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of engineering school curricula in response to environmental challenges has been a focus for researchers around the globe. The work on the engineer in the training remains a very important point for ecologically responsible projects, because these profiles will be leaders and responsible for projects, so they will be the ones who propose and decide the development of a project, so if they are eco-responsible profiles, eco-responsible projects will be developed. In this perspective, and like several researchers, we are interested in the integration of environmental and social concerns in engineering training through the development of a pedagogical model. But the difference and the discussion focuses on the criteria of development and the necessary skills that these models must carry to be effective in the face of the desired objectives. To this end, this research work proposes the stages of preparation for the design of our model. We start with the construction of the criteria and competencies necessary for the development of a pedagogical model. The objective of this study is to extract from about twenty contributions that intersect with our keywords and our theme in several countries such as the United States, France, Finland, Denmark, China, Malaysia, Singapore, New-Zealand and Morocco. These contributions deal with pedagogical models in training and also the novelties concerning ESD, We analyzed these contributions to create a catalog of competencies and criteria to determine the most crucial elements in a training model that is incongruent with ESD to create benchmarks to measure against. This study will be done through the SWOT matrix (Strengths, Weaknesses, Opportunities, Threats) where we will compare the criteria obtained with the pedagogical models treated in the literature review. This work aims to identify the modalities of the design of different pedagogical models, the needs of the socio-economic world and develop a framework for an effective model to train eco-responsible engineers.

## 2 Literature Review

The development and improvement of education by integrating environmental issues is the concern of many researchers, the focus is mainly on pedagogical models and especially on pedagogical approaches in interaction with the socio-economic world in the broad sense. To this end, there are transformative pedagogical approaches proposed by several researchers in the face of ESD, and key competencies to train eco-responsible engineers. So from our literature review, we had 7 pedagogical models and 14 contribution analyzing the opening doors to the eco-responsibility and ESD themes, some of them giving the different competencies that a engineering student should learn in the curriculum, others gave an idea about the nature of the model that is going to be relevant with the environmental challenges and ESD, and the last part of contributions, analyze the role of managers and school's staff and their engagement in the ecological and sustainable development topics. The analysis of the literature review gave us six out of seven pedagogical approaches that could be sufficient for the comparative study; they are shown in Table 1.

**Table 1.** A list of pedagogical models used in the comparative study

| Contribution | Model | Year | Model's process | Goals | Country |
|---|---|---|---|---|---|
| (Mharzi, 2020) | PBL (Project based learning) | 2021 | - Classroom training<br>- Project based training (Define, Collecting, Analyze, Execute the solution, Control) | Working on environmental and social problems via integrating the students into some projects to be more conscious about the environmental topics. | Morocco |
| (K. Kovesi, 2020) | DCL (Diversifying Competences Learning) | 2021 | - PBL (Project based learning)<br>- IBL (Internet Based Learning)<br>- CL (Classroom Learning) | This model gives the opportunity to the future engineers to have a large base of competences in multiple fields to well understand the SDG's. | France |
| (S.Y.Teh, 2020) | STEM (Science, Technology, Engineering, Mathematics) | 2021 | - Define<br>- Collecting<br>- Analyse of solutions<br>-Taking the most appropriate solution<br>-Control and standardize | Treating the environmental problems by capitalizing the technical, scientific and mathematical knowledge of students. | Malaysia |
| (N. Wittayakhom, 2020) | STEAM (Science, Technology, Engineering, Art, Mathematics) | 2020 | - Define<br>- Collecting<br>- Designing a creative solution<br>- Executing the solution<br>- Control and improving | Treating the environmental problems by creating innovative solutions and use the creative thinking of students. | Thailand |

(*continued*)

**Table 1.** (*continued*)

| Contribution | Model | Year | Model's process | Goals | Country |
|---|---|---|---|---|---|
| (T. T. Wu, 2020) | CDIO (Conceive, Design, Implement, Operate) | 2020 | - Preparation<br>- Implementation<br>- Presentation<br>- Evaluation<br>- Revision | Considering a project as a problem and trying to use collaborative, innovative and critical thinking to solve the problem in a creative way. | China |
| (Y. Wang, 2021) | PBL SCAMPER (Substitute, Combine, Adapt, Modify, Produce, Eliminate) | 2020 | - Conception<br>- Design<br>- Implementation<br>- Operate | Work on ecological projects by giving the opportunity to all the classmates so they can give their opinion, so we can have a lot of solutions, and achieve the collaborative thinking. | China |

## 3 Methodology

Our work consists of synthesizing the necessary criteria of a pedagogical model (competencies, characteristics) to train an eco-responsible engineer first, and to design the SDGs second. Then, based on the literature review we have done, we have synthesized a catalog of competencies as shown in Table 2. The criteria selection was based on the categorization of contribution's fields, there is some contributions put the spotlights on the competences that a curriculum should contain to form a responsible engineer face-off eco-responsibility and ESD, so we limited these competences under three main categories, technical, non technical and attitude's criteria. Also, some contributions analyzed the nature of a relevant model and its characteristics to respond to the ESD and eco-responsibility themes, that's why we took these characteristics under one category named "The nature of the model". Finally, we used the contributions that analyze the different competences that the managers and school's staff should develop to provide a good management of the ESD and eco-responsibility approaches, so we put them under one category called "Competencies needed by the managers".

**Table 2.** Criteria concluded from the literature review

| Technical Criteria | Non Technical criteria | Attitude criteria | The nature of the model | Competencies needed by the managers |
|---|---|---|---|---|
| - Mathematical competencies<br>- Digital competencies<br>- Economical competencies<br>- Research competencies<br>- Technical competencies<br>-Multidisciplinary<br>- Problems resolution<br>- Interpretation and conception's capacity<br>- Conceptual comprehension<br>- Innovation<br>- Entrepreneurship<br>- Decision Making<br>- Projects management<br>- Organization<br>- Problematic thinking<br>- Knowledge about environmental responsibility and ESD<br>- "Cleaner Production" thinking<br>- Engagement in the conservation and protection of the environment | - Leadership<br>- Conflicts management<br>- Negotiation<br>- Communication<br>- Foreign Languages<br>- Listening<br>- Team work<br>- Intercultural skills<br>- Critical thinking<br>- Holistic thinking<br>- Systemic thinking<br>- Creativity<br>- Analytical thinking<br>- Stress management<br>- Time management<br>- Multi-perspective<br>- Collaborative thinking | - Global awareness<br>- Social responsibility<br>- Sustainability awareness<br>- Environmental awareness<br>- General knowledge<br>- Long-term thinking<br>- Respecting others<br>- Open minded<br>- Agility, adaptability<br>- Curiosity<br>- Empathy<br>- Emotional intelligence<br>- Ethic awareness<br>- Personal engagement<br>- Civic competencies<br>- Interpersonal competencies<br>- Healthy lifestyle capacity | - Sustainability<br>- Green competencies<br>-Transformative politic<br>- Development of human resources<br>- Flexibility<br>- Continuous improvement approach<br>- Harmonization with the socio-economical world<br>- Diversification of actors<br>- Equity between Soft/Hard Skills<br>- action-orientation approach<br>- Diversity training of all the stakeholders<br>- Introduction to ESD<br>- Treatment of the environmental issues<br>- Interactive, participative, autonomy approach<br>- Auto-evaluation<br>- Problem, Action based learning<br>- UNESCO, GAP criteria | - Capacity of recognizing a manager and a Leader<br>- Distributive leadership<br>- Integrating the school community and personnel<br>- Administrative Competencies<br>- Cooperative organizational team<br>- Strategic Management<br>- Anticipation of the model's lifecycle<br>- Environmental responsibility and ESD's knowledge<br>- Capacity of communicating with the stakeholders<br>- An open vision on the long-time<br>- Open, and innovative mentality<br>- Knowledge of SDG's<br>- Capacity of taking decisions<br>- Capacity of showing the civic awareness and the social responsibility<br>- Ecological awareness |

We have categorized this catalog into two types, skills that an engineer must master to be eco-responsible (Content of the model), skills needed in the leaders of the model so that they can capture the ecological transition and characteristics about the nature of the model (management of the model). The competencies that characterize the content of a model are divided into three: technical, non-technical and attitude competencies. The methodology of work consists of making a benchmarking study by determining the important and critical criteria through two questionnaires, the first has the role of filtering the catalog of criteria mentioned in the catalog, and the second is to measure the importance of the criteria selected in the questionnaire 1 and synthesize the most important competencies that a pedagogical model must meet the eco-responsibility and to understand the basics of ESD. The choice of the questionnaires is made to reach all the members of the work team because one member was far from Morocco (New Zealand), and also because the questionnaires on Google Forms are more flexible and quicker in terms of response. The two questionnaires are shared between us by our mailboxes, with an explanatory document to know how to answer and to explain how we are going to treat these answers, the treatment was manual because we are 6 people in the team. Afterwards, we made a comparative study between the pedagogical models mentioned in Table 1 to know the points of divergence and convergence between the models according to the critical criteria chosen from the questionnaire 2, through the SWOT matrix, identifying the different common points and intersection between the models to open the door of identification of the nature of the model. By classifying all the criteria that we have synthesized in a SWOT matrix appropriate to each educational model. And through the intersection SO (Strengths- Opportunities), ST (Strengths-Threats), WO (Weaknesses-Opportunities), WT (Weaknesses-Threats), we have addressed the feasibility and correspondence of these pedagogical approaches with eco-responsibility. This work will help us to study if these models really meet the recommended criteria and the possibility of combining these models to create an effective pedagogical device in engineering schools to address environmental issues.

## 4 Findings

The work done in this article began after the literature review, with the creation of a criteria repository (80 criteria) that includes the necessary competencies for a successful educational model in the face of eco-responsibility. After the construction of the criteria, a Benchmarking study was done, starting with a filtering work (Questionnaire 1), measuring the criticality of each criterion (Questionnaire 2), and finally a comparison work between the proposed pedagogical models to study the adaptability of these trendy approaches in relation to eco-responsibility and ESD.

### 4.1 Results of Questionnaire 1

This questionnaire, created in Google Forms, and shared between the members of the working group who have a pedagogical experience between 20 and 35 years, has the objective of minimizing the criteria repository created, in order to facilitate the study and also to choose the basic criteria that a model must include as competences. This questionnaire consists of 2 questions (According to your experience and knowledge, what are the micro-criteria necessary to build an efficient pedagogical model, according to your experience and knowledge, what are the macro-criteria necessary to build an efficient pedagogical model?) question 1 is divided into three (Technical, non-technical, attitude) and question 2 into two parts and provokes the capitalization of the experience of the team members. The results of the questionnaire showed that among the technical criteria that a model must have to form an eco-responsible engineer are technical skills, digital skills, problem solving, interpretation and design ability, innovation, decision making, project management, problematization and a background on eco-responsibility and ESD. For the non-technical criteria, the team voted for Leadership, Communication, Foreign Languages, Teamwork, Critical Thinking, Systems Thinking, Creativity, Analytical Thinking, Stress Management and Collaborative Thinking. For the attitude criteria, the choice is limited to global awareness, social responsibility, sustainability and environmental awareness, respect for others, agility, adaptability, curiosity and finally interpersonal skills. For the criteria of identification of the nature of the model, the results show that the green skills, flexibility, balance between Soft/Hard Skills, clarity and diversity of the model, handling of environmental issues and interactivity of the model. And finally, for the necessary criteria that an educational leader must master for ESD are anticipation of the model's development, integration of the school's community and staff, knowledge of eco-responsibility and education for sustainable development, the ability to influence stakeholders and communicate, an open, collaborative and innovative mindset, knowledge of the goals of sustainable development, the ability to show civic awareness and responsibility social, ecological and environmental responsibility.

### 4.2 Results of Questionnaire 2

This questionnaire which was also created on Google Forms, distributed on the same members of the questionnaire 1, has the objective to know which are the most important criteria to be used in the study so that we can make the Benchmarking of the educational models according to these criteria. The list of criteria is minimized from 80 criteria to 40. The questionnaire is based on the criticality of each criterion, by choosing one of the three boxes (Not very important, Important, Very important), and each member must choose one of these three proposals. The questions are (According to your experience and knowledge, what are the important micro-criteria for building a successful

educational model? According to your experience, and your knowledge, decide which macro-criteria are important to build a successful pedagogical model). The results of the questionnaire showed that among the technical criteria necessary in a pedagogical model we find technical skills, interpretation and design capacity, innovation, project management, problematization and also the possession of knowledge regarding ESD and eco-responsibility. In the axis of non-technical criteria, communication, foreign languages, teamwork, critical, analytical and collaborative thinking, systemic thinking, creativity and stress management are the most important criteria for a successful model. Regarding the attitude criteria, social responsibility, sustainability and environmental awareness, respect for others, agility, adaptability and curiosity are the competencies chosen in this section. For the criteria that designate the nature of the model, from the questionnaire, what is chosen is the model that includes green skills, flexibility, balance between Hard/Soft Skills, clarity and diversity of the model, dealing with environmental issues and finally the approach used must be interactive. And finally, the criteria of the model are chosen such that a leader must influence and communicate with stakeholders, an open, collaborative and innovative mindset, knowledge of the sustainable development, the ability to demonstrate civic awareness and social responsibility, environmental and ecological responsibility, community integration and school staff, and finally the anticipation of the model's development.

### 4.3 The SWOT Matrix

In this step, a comparative study between the pedagogical models was made through the SWOT (Strengths, Weaknesses, Opportunities, Threats) matrix according to the criteria we have chosen. All the criteria were dispatched on the four cases of the matrix, so we can enlarge our critical view, and find out the similarities and differences between all the pedagogical approaches reviewed.

## 5 Discussion

By analyzing the pedagogical approaches reviewed by the SWOT matrix, we had a clear image of the position of each model face off the environmental issues and also the possibilities of an opening door to ESD. Each model is treating problems (PBL, PBL SCAMPER, STEM), some of them transform it to projects, others try to put innovative solutions (STEAM, CDIO) and others trying to enlarge the circle of competences to tackle the environmental problems (DCL). The SWOT matrix showed us that there are similarities between the models, as all models face the same risks and have the same opportunities. So our treatment is to discuss the intersections between the four elements of the SWOT matrix by following the strategies: (Strengths-Opportunities) using the

strengths to take advantage of the opportunities, (Weaknesses-Opportunities) which is used to improve the weaknesses to seize the opportunities, (Strengths-Threats) which is used to use the strengths of the model to protect itself from the different threats, and lastly (Weaknesses-Threats) to decrease the weaknesses of the company to avoid the threats.

### 5.1 Strengths-Opportunities Intersections

For the CDIO, STEAM models, the strengths are almost the same, the exploitation of the technical skills, creativity, innovation and personal management or communication skills of the engineering students will serve to take advantage of opportunities to have creative ecological solutions, to design innovative eco-responsible and socially responsible deliverables by capitalizing on the technical, personal and also interpersonal potentials of the engineering students. Thus a CDIO or STEAM model or a combination of both can ensure innovative and creative engineering profiles that take advantage of environmental themes and projects to create environmentally and socially responsible solutions. On the other hand, PBL, PBL SCAMPER, STEM and DCL are also close to CDIO and STEAM, but the principle is to train fully competent technical and managerial people who can find the optimal solution and not necessarily a creative solution to address environmental issues. In any case, since these models are applied in several areas, there is an opportunity to address the theme of eco-responsibility.

### 5.2 Weaknesses-Opportunities Intersections

The balance between soft/hard skills, and also problematization with a lack of creativity and also innovation are very important skills to improve in order to deal with an issue like eco-responsibility or ESD which requires a diversified profile in skills. So working on these skills also ensures an eco-responsible profile, which understands what a problem or issue is, which has a critical mind and which is technically and socially balanced.

### 5.3 Strengths-Threats Intersections

The focus on technical, personal, interpersonal and managerial skills in the pedagogical model pushes the leaders to be more aware and competent in the technical, managerial tools and to have an ecological awareness and also a knowledge regarding ESD, in order to bring to the engineering students the environmental themes and the good capitalization of the skills acquired in the course, the projects and also in the school environment. What is added for the CDIO and STEAM is the creativity and innovation tool, so the leaders will be obliged to know how to anticipate the development of the model and the innovative spirit. The concern of foreign languages is also imposed but if the work on the clarity and diversity of the model is well adopted, it will be easy to see what is happening in the world and yet know several languages afterwards.

### 5.4 Weaknesses-Threats Intersections

In this component, there is a possibility to merge between STEAM and any model, because the former can bring in addition to the problematization and critical thinking skills, it can also bring and cover the lack of innovation and creativity in the model, which makes the effect of lack of skills in leaders a point obliged to be improved to give a very good training for eco-responsibility and ESD to engineering students.

## 6 Conclusion

The study shows that there is a great opportunity to address environmental issues in all proposed educational models by bringing in themes related to eco-responsibility and also ESD, with a challenge for leaders to master managerial skills and knowledge regarding ESD. Within the models, it is clear that the strengths and weaknesses are similar, with a plus for STEAM and CDIO regarding innovation and creativity, and since all the models are flexible and applied in several areas, there is the possibility of collaboration especially with CDIO and STEAM, to strengthen the strengths and diminish the weaknesses in order to form a model that is rigid and less fragile, and also diversified with an opportunity to work on eco-responsibility and a draft towards ESD. This work on the various existing pedagogical models and on the skills to be developed in the eco-responsible engineer is very important, but it will have to be crossed with the reference frame of competence of the mechanical engineering and the learning achievements, previous works of the team (Aithaddouchane, 2019). This study will serve as a basis for the creation of a model for the implementation of the environmental responsibility dimension in technical and socio-technical projects in engineering schools.

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