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TOWARDS A NEW DESIGN OF SUSTAINABLE SOCIAL DEVELOPMENT PROJECTS THROUGH PRECISION AGRICULTURE AND DATA SCIENCE IN THE EDUCATIONAL MODEL TEC21

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ABSTRACT
In the 2025 strategic plan, the mission of Tecnologico de Monterrey is to train people with a humanistic vision and to be internationally competitive in their professional field. During the last 15 years, through the design of social development projects in marginalised areas of the *Sierra Gorda* of Queretaro, which undergraduate students carry out during their university studies, different projects have been implemented in which added value is given. Agricultural products are based on local supply chains for raw materials and the help of the government of Guanajuato and Querétaro to bring these products to the market. Furthermore, through the studies carried out on different seeds and crops in the Experimental Agricultural Field of the Tecnologico de Monterrey, CAETEC has created a new methodology to increase the productivity of these production units and make them the economic engine to eliminate poverty in marginalised areas by applying design techniques, project management, statistics, design of experiments, and data science. The use of precision agriculture at CAETEC has generated valuable information on cultivation methods to improve productivity and information obtained from greenhouses built using the principle of Agritronics that are operated by renewable energy to harvest agricultural products in remote areas and are more marginalised from the country. Students lived a social experience apart from the academic knowledge acquired to design sustainable social development projects presented in this paper.

Keywords: Precision agriculture, data science, design of experiments, higher education, educational innovation

1 INTRODUCTION
The economic crisis of 1994 was the trigger for the development of social projects to generate alternatives to help low-income people have a stable economic life. According to CONEVAL (2020) [3], in Mexico 43.9% of the population is living in poverty, this is equivalent to 55.7 million people, of which 8.5% live in extreme poverty (equivalent to 10.8 million people). Therefore, creating social projects to improve the quality of life for this population percentage is of great importance; that is why the Tecnologico de Monterrey committed to society and began to design activities and projects of agro industries within its programs to help marginalised areas.
As an educational institution, Tecnologico de Monterrey has as its mission to develop in its students the competencies of ethics, citizenship, and payment of the social mortgage; this mission is achieved by designing space where its students put into practice their knowledge for solving real and social problems through activities (Villanueva, 2018) [15]. Week i is an example of this; it is a project where students take part in addressing a specific social issue, developing disciplinary and transversal competencies, with the accompaniment and guidance of faculty and education partners (Tec. de Monterrey, 2017)[14]. Data science (DS) plays a key role for successful collaborations between institutions and partners. DS refers to an interdisciplinary field that involves a series of methods, processes, and systems, with the aim of extracting knowledge from data. It has proved to be of great application in very different areas, particularly in Education (Klašnja-Milićević et al., 2017) [8]. In this project, data science in precision

agriculture allowed the iteration of possible spatial and temporal variations to improve existing agricultural practices (Maohua, 2001) [9].
This document summarises the experiences in the design of databases both in classes with the immersive experience with Centro Agrícola Experimental del Tecnologico de Monterrey (CAETEC) which is a living laboratory focused on the practice of techniques and theory to maximise the experiential learning of students according to the TEC 21 Model of the Tecnologico de Monterrey (challenge-based learning) and the immersive experiences of week i to design and manage social development projects through teams. Through Solidarity Engineering, that is defined as the ability to design and execute social development projects through multidisciplinary groups based on simple and engineering solutions (Acuña *et al.*,2017) [1], together with a group of teachers and students, an activity called "The Solidarity Route of *Sierra Gorda*" was implemented. The objective was to identify spaces in which students apply their knowledge with a positive impact generating a "win-win" relationship with the community.

2 DEVELOPMENTS

The main purpose of the Solidarity Route is to achieve poverty reduction through social development projects. Hence, Week i looked the design of community interventions that were based on merging the culture and customs of each community with Solidarity Engineering, DS, and technology of the institution. It also was looking for designing solutions to their daily problems, contributing to the reduction of poverty in these areas through productive designs (González, 2018) [6]. This activity also was designed to sensitise students about poverty and the needs of the poorest.

2.1 Methodology for social projects

First, it was important to design the Solidarity Route activity based on a humanistic vision with the philosophy of Solidarity Engineering. The Solidarity Route of the *Sierra Gorda* was designed to have a duration of 5 days. The activity was supported by a team of professors from different specialties of the Tecnologico de Monterrey Campus Querétaro, civil society organisations, government entities at municipal, state, and federal levels, and the beneficiary community, and of course the students. This activity was carried out in neighbourhoods with a high rate of marginalisation and poverty located in the city of Guanajuato and Querétaro.
The project was organised in three stages: diagnosis, theorising, and validation. The diagnosis was centred first in the definition problem. The civil society, municipality, and community together with the teachers of the Tecnologico de Monterrey discussed the main problems and needs of the communities. Only one community was impacted per activity. Design thinking was the cornerstone for the design of the activity of this stage to define the objectives that must be achieved in week i. The Systemic design was used to co-create the definition of the intervention of internal and external actors of the project.
In the theorising part, the formalisation of the diagnosis must be done; in this stage is where the definition of all the actors, sponsors, deliverables, procedures, problems, activities, and the design of all the possible solutions are done. For the validation phase techniques of Design thinking such as brainstorming, mind maps, among others were used to abstract the definition of the problem and to generate all the activities. It is at this stage where the calendar of the activity is proposed as well as the commitments acquired for all the actors involved in this project.

2.2 Social development projects as a source of data

There were other factors that had to be considered for the implementation of the Solidarity Route activity. Although the main purpose of this activity was to help the poorest communities, there was a wonderful opportunity to get data from the communities that can be analysed and tested in the CAETEC as a means to improve future projects into the communities. For example, greenhouses and backyard gardens installed must have a slogan that the beneficiaries must register the information to continue feeding the databases.
Once the database was gathered, then it was possible to integrate and improve the harvest with the help of precision agriculture that is defined as: “A management strategy that gathers, processes, and analyses temporal, spatial, and individual data and combines it with other information to support management decisions according to estimated variability for improved resource use efficiency, productivity, quality, profitability and sustainability of agricultural production" [7].

Together with institutions as SADER and INEGI, it was possible to obtain sensitive information regarding the Bajío region to build the databases. The collection of data of important variables as: Soil characteristics, Crop potential, Active components of the crops, Hydrography, Carbon footprint, and climate impact is needed to implement the designed projects. The information provided by CONEVAL was used to select the municipalities with the highest level of poverty. The microclimates at *Sierra Gorda* allow the sowing and exploitation of different agricultural products. It is worth noting that it was necessary to know in advance an overlook of the crops and roots that naturally occur and the possibility that those crops and roots can grow there, this allowed to determine if the designing of a project was going to succeed.

2.3 The effect generated by the development of social projects

Once that the three initial parts are solved, then it is possible to determine the needs for the communities, for instance the construction of greenhouses, backyard gardens, rehabilitation or renovation of buildings or sport courts, seek solutions for the overproduction or lack of production of some fruit or nuts, among other necessities. The team of the activity was confirmed by one teacher and students belonging to bachelor's degrees in marketing, or several areas of Engineering such as industrial, mechanics, mechatronics, food chemistry, biotechnology, civil, and agronomy.

In 2016, week i was implemented in one of the poorest towns in Mexico, Victoria-Guanajuato; and it was analysed that for greenhouses installation the possibility of the implementation of Agritronic sensors which work with renewable energy. Nevertheless, the greenhouses were installed, and the community was trained to maintain, operate and collect the produced data. Several backyard gardens were implemented with the commitment to inform any incident and the quality of the crops. Figure 1. Projects such as elaboration of nectars, fruit paste, sweets from the region, were implemented as well. The machinery for peeling some nuts, parts of some machinery or other kind of help to the community was also implemented.

Figure 1. Backyard gardens in Week i 2016 at Victoria, Gto. (Own source)

In 2017, week i was implemented in the same municipality but in a different region. For that occasion, several fruits were used to produce jams or fruit paste. The main idea was to generate products with added value. Again, the implementation of greenhouses and backyard were done with the agreement of collection of data and to inform any incident during the documentation and to make a statistical treatment of the project (González, et al., 2018)[4]. Figure 2.

Figure 2. Production of jams in Week i 2017 at Victoria, Gto. (Own source)

For the week i of 2018, the Solidarity Route worked in the municipality of San Luis de la Paz in the community of Rancho de Guadalupe of Guanajuato. In this region, the inhabitants had already greenhouses built in the 70´s, therefore the project objective was to reactivate their greenhouses, with new roofs and a modern way of irrigation, additionally, backyard gardens were also constructed. In this community there was a greater need to improve their agro-industrial approaches (cheese and yoghurt factories). Thus, the objective for the teams was the rehabilitation of the agro-industry area, as well as

the establishment of a children's sports centre and the restoration of the community's chapel that had structural damage (Cáceres, 2018) [2]. Figure 3.

Figure 3. Rehabilitation of the greenhouses in Week i 2018 at San Luis de la Paz, Gto. (Own source)

For the week i of 2019, the Solidarity Route worked with *La Estacada* and *Tzibantza* in the State of Queretaro, the activity consisted in the designing and building family gardens, greenhouses, and ovens for bread; give courses to the inhabitants about food processing; design and implement a steamboat's festival illuminated by paper balloons, to celebrate the day of the dead for tourist attraction. During the pandemic, week i was suspended, this caused several problems in the collection of the data. It was when the CAETEC entered the project to help with data collection. CAETEC already had greenhouses and irrigation systems, a cattle herd focused on milk production, drones and sensors to collect information, and some many different projects that could help to improve the life of the poorest farmers. Based on the information provided by CAETEC and with the use of mathematical models, it was possible to find the best food blends of cows based on the nutritional values prioritising the cost for the optimisation of farmers' economic resources and looked for the best combination of nutrients of the cows (Saavedra et al, 2022) [11]. Together with the information obtained from the greenhouses and backyards, CAETEC and the communities it was possible to improve the development of agricultural products, and furthermore, impact the poorest people to improve their harvest.

3 RESULTS

With the implementation of the social development projects carried out in *Sierra Gorda*, several goals were achieved. The most important was that the activity contributed to help the poorest communities in several areas by improving the condition of the community according to their needs. AgroProject databases were used to collect the data. All the characteristics were collected by region, this provided, and it will continue providing, important information that permits going back to the communities in the next years with new projects and proposals of agro-industrial areas. In this database, characteristics of the crops and the areas of high productivity in the *Sierra Gorda* were entered. It was possible to test and contrast with the active substances; a suggestion for sowing a product is added with a mathematical model.

The second goal achieved was the possibility of collecting data for each region as the characteristics of the region. The variables of interest were types of farms, climate, orography, hydrography, and impact on biodiversity. The information collected in the *Sierra Gorda* activity together with Precision agriculture and DS made it possible to experiment with new techniques for sowing different products that can be replicated in agro-industrial projects, to improve quality and richness of nutrients. One example of this practice was the results obtained with the *chilcuague*, which has been used for many years as a bactericide and can treat toothache, the aim of the research was to evaluate if the *chilcuague* that grows wild has the same characteristics as the *chilcuague* reproduced in farmland, and if the *chilcuague* has the same characteristics in the three geographical regions (Atarjea, Xichú, and Victoria). The two-factor factorial design is the statistical technique that can be used to validate this kind of experiment. For this model each replicate of the experiment contains all treatment combinations and it is necessary to have at least two replicates of the treatments. The order in which the observations are going to be taken will be at random so that this design will be a completely randomised design. All the factors are assumed to be fixed. The treatment effects are defined as deviations from the overall mean and the effects of the interactions are fixed and add up to zero (Montgomery, 2011) [10].

The effect model i was given by:

$$y_{ijk} = \mu + \tau_i + \beta_j + (\tau\beta)_{ij} + \epsilon_{ijk} \qquad (1)$$

where:

□ is an overall mean effect,
τ_i is the effect of the ith level of the row factor A,
β_j is the effect of the jth level of column factor B,
$(\tau\beta)_{ij}$ is the effect of the interaction between i and j
ϵ_{ijk} is the random error, Normal(0, □^{2})
For the experiment, ten plants were taken from wild areas and ten were grown in farmland (Factor A) in the three different geographical areas (Factor B: Atarjea, Xichú, and Victoria). For this kind of design there are three hypotheses to be tested:

- The means of the amount of active component (affinin) of the chilcuague in the three geographical areas are the same.
- The mean of the amount of active component (affinin) of the chilcuague in farmland is equal to the mean of the amount of active component of the chilcuague that grows wild.
- The mean of the amount of active component of interaction between geographical area and sowing type (affinin) of the chilcuague in farmland is the same.

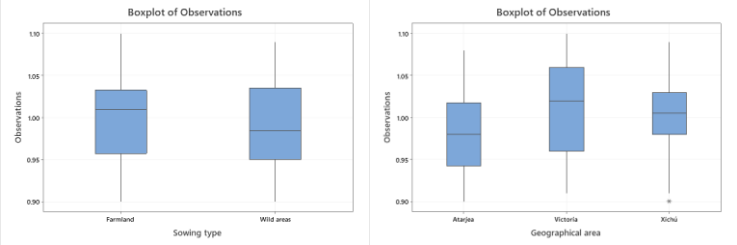

Figure 4. Boxplots of the amount of active component (affinin) of the chilcuague of Sowing type and Geographical area (Own source)

The analysis of the data was done with Minitab 19 Software. As it can be seen in Figure 4 the behaviour of the two factors is pretty similar among the categories. In order to probe that, an ANOVA was computed, (Table 1) and it was found that the geographical area, the sowing type, and the interaction are not significant at 95% of confidence level with p-values of 0.2484, 0.6052, and 0.1044, respectively. In other words, there is no difference in the amount of active component (affinin) between geographical areas, sowing types, and their interaction.

Table 1. ANOVA Table for two-factor factorial design

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Geographical area	2	0.0085	0.0043	1.4293	0.2484
Sowing type	1	0.0008	0.0008	0.2703	0.6052
Geographical area*Sowing type	2	0.0141	0.0070	2.3564	0.1044
Error	54	0.1611	0.0030		
Total	59	0.1845			

4 CONCLUSIONS

The results presented in this document are important not only for the communities where a lot of people from the poorest regions were benefited, but also for all the actors involved in the social projects. Soft methodologies were used to define activities and attitude for week i based on 4 types of thinking: concurrent, systemic, prospective, and resilient. Moreover, the students lived a social experience apart from the academic knowledge acquired, it was found in the final comments of students that the involvement of the project helped them empower themselves and the community additionally they also mentioned that it was an enriching experience where the improvement of local products induced positive changes in the working lifestyle of the inhabitants, leading them to have a better life. It has been proved that there is no difference between the locations nor in the type of sowing. This opens opportunities for sowing more types of products in different areas. The implementation of data science in development projects with precision agriculture can be a key part in ethical decision-making and a tool for resource

optimisation. The gaps of inequality in the communities could be shortened by strengthening local economies. But more importantly, these projects are highly replicable, and have the characteristics of being a long-term benefit led by the communities that decide to adopt them.

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