Chapter 1 Pedagogical activity to teach the concepts of renewable energy to Mexican engineering students

Capítulo 1 Actividad pedagógica para enseñar los conceptos de energías renovables a estudiantes mexicanos de ingeniería

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Abstract

This paper describes a dynamic activity to teach the concepts of renewable energy and evaluates its effects on engineering students in Mexico. The dynamic activity is based on variations of percentages of energy consumption proposed by a teacher and the participants using bean seeds. A total of 92 students of Renewable Energy Engineering from three different periods involved the study. The participants were divided into groups, and presented a report where they demonstrated their level of understanding. Using the One-Way ANNOVA test determined differences between their proposals and the teacher ones and interpreted the level of participants' knowledge acquired. A survey was also implemented to examine the effects of understanding the topic and detect discrepancies between directed questions and their proposals. The results showed that the dynamic activity helps participants with their difficulties in understanding the topic. It was found satisfactory outcomes when the dynamic activity is applied face to face.

Proposal, ANNOVA test, Energy sustainability, Energy consumption

Resumen

Este artículo describe una actividad dinámica para enseñar los conceptos de energía renovable y evalúa sus efectos en estudiantes de ingeniería en México. La actividad dinámica se basa en variaciones de porcentajes de consumo de energía propuestos por un docente y los participantes utilizando semillas de frijol. Un total de 92 estudiantes de Ingeniería en Energías Renovables de tres períodos diferentes participaron en el estudio. Los participantes fueron divididos en grupos, presentaron un informe donde demostraron su nivel de comprensión. Mediante ANNOVA One-Way se determinaron diferencias entre sus propuestas y las del docente, y se interpretó el nivel de conocimiento adquirido por los participantes. También se implementó una encuesta para examinar los efectos de la comprensión del tema y detectar discrepancias entre las preguntas dirigidas y sus propuestas. Los resultados mostraron que la actividad dinámica ayuda a los participantes con sus dificultades en la comprensión del tema. Se encontraron resultados satisfactorios cuando la actividad dinámica se aplica cara a cara.

Propuestas, Prueba ANOVA, Sostenibilidad energética, Consumo de energía

1. Introduction

Conservation of sources energy is one of today's most critical issues of the world (Dunlop, 2019). Regarding the rapid reduction in supplying non-renewable resources, nations are improving policies and strategies that promote a mixture of renewable and non-renewable energy resources (Sharvini,2018). However, the current energy model is still characterized by constant growth in global energy consumption based on fossil fuels (IEA,2020). In the case of Mexico, with the discoveries of important oil fields, the Mexican energy system has been evolving towards a pattern of energy production and consumption based on hydrocarbons. Currently, the total demand for primary energy in Mexico reflects the dependence on fossil resources with 89%, 2% on nuclear energy, and 9% on renewable energy sources, mainly hydroelectricity (4%) (SENER, 2018).

Mexico faces a deterioration in its natural resources mainly due to the expansion of agricultural, livestock, forestry and fishing productive activities, which have been developed to obtain a greater economic return without considering the damage caused to the environment, the social and economic impacts (Islas, 2010). One of the areas for the promotion and diffusion of energy resources is the education systems (Jennings, 2009, Kandpal et al., 2014), especially vocational-technical education (Kacan, 2015). Under this context, the Government of Mexico and the United Nations System (UNS) signed the United Nations Cooperation Framework for the Sustainable Development of the United Mexican States for the period 2020-2025 (UNESCO, 2022), searching to promote education as the basis for generating a more viable society and promoting the integration of sustainable development in the school education system at all levels (OMS, 2013).

To fulfil this international commitment, Mexico has taken on the task of developing the Environmental Education Strategy for Sustainability (Gonzalez, 2000), in an effort to organize and promote the activity in the field of environmental education in the country.

In this sense, Higher Education Institutions consider that environmental education should be a common transversal axis to the higher education curriculum so that students obtain knowledge, become aware of their environment and acquire values that promote favourable behaviour towards the environment (Gerritsen et al. 2006, Jennings, 2009, Kandpal et al., 2014).

The teaching system on environmental education in Mexico has directed its attention to the design of plans and programmes. However, they have put aside teaching-learning in the classroom. Authors like Juarez et al. (Juarez et al., 2006) reported that when environmental programmes are tried to implement in the classroom, professors and educators are not suitably qualified for developing techniques or strategies that increment students' interest and acquirement of knowledge in this topic. Reyes et al. (Reyes et al., 2019) identified that there is a lack of collaborative work to deal with problems on sustainability in the classroom. Sosa et al. (Sosa et al., 2010) pointed out environmental education has deficiencies to educate Mexican students, some of them are that the majority of schools do not have renewable energy laboratories, the programmes lack practices or activities for achieving a deep understanding of the topic and the spaces, infrastructure and support are insufficient to teach and promote the environmental topics.

In recent years, prior works have examined strategies for improving learning processes of renewable and non-renewable energy resources. This is because it is known current teaching methods are not always sufficiently motivating and practical; thus, students reduce their interest and acquirement of knowledge in this topic (Alawin et al. 2016, Friman, 2017). Under this context, Massa et al. (Massa et al., 2011) proposed to teach solar energy via problem-based learning, where the students solve homework problems, lectures and engage in structured-type laboratory activities. Taking into account such an approach, problems were designed to engage secondary and post-secondary students in authentic real-world problem-solving focused on a broad range of contemporary issues of sustainability; including solar and wind energy, clean water, energy-efficient lighting, sustainable agriculture, and "green chemistry" in personal care products. In (Lund et al., 2001), authors developed "picture book" laboratory sessions for isolated students who cannot attend on campus. These enable them to learn techniques of data analysis and experimental design. Torres et al. (Torres et al., 2014) introduced a video-sharing educational tool applied to teaching in renewable energy subjects that consists of a web channel of an online platform, which integrates multimedia materials that show the techniques and technology used to produce electricity or thermal energy from renewable resources. This learning tool was applied and used as a support in two ambits, face-to-face and non-face-to-face education, in two different educational levels: undergraduate and postgraduate education. The results showed that the students improved their understanding of the theoretical concepts.

Supported by the above, this paper describes and evaluates the effects of a dynamic activity to teach the concepts of renewable energy to engineering students in Mexico, which is based on teaching-learning techniques with dynamic activities and games (Jennings, 2009). Through this dynamic activity, students gain an increment of understanding of the effect of energy consumption, the differences between renewable and non-renewable resources and the need to implement new strategies on energy use in the future. This research considers a report and a survey. In the report, the participants demonstrate qualitatively and quantitatively the level of understanding with graphical proposals, and the teacher examines the effects of this activity. With the survey applied to each student, the teacher detects discrepancies between directed questions and the proposals made as a team. Using One-Way ANOVA test we determine differences between the proposals of teachers and participants and interpreted the level of participants' knowledge acquired for the three different periods.

2. Research Method

2.1 Participants

The regarded sample consisted of bachelor students from Instituto Tecnológico de la Laguna in Coahuila, Mexico. A total of 92 students in 1st semester of the Renewable Energy Engineering degree and a teacher helped by two master's students were involved in this study. The participants were part of the Introduction of Renewable Energy course corresponding to the years 2020, 2021 and 2022. They were divided randomly into 18 groups, as shown in Table 2.1. The teacher and the two master's students were assigned to explain the rule of the activity and the master's students in order to control their performance.

Table 2.1 Courses and number of participants

Period	Descripción	Number of participants
September 2020	6	32
October 2021	6	32
April 2022	6	28
Total	18	92

Source: Self Elaboration

2.2. Materials

For this dynamic activity, each participant needed a paper bag, which contained 100 beans; 90 of these were black, and the other ten were white. A number of extra beans were available for variants on the proposed approach. Figure 1.1 shows as an example, the table that each participant carrying out the activity.

Figure 1.1 Table of renewable and non-renewable resources per decade

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Activity
Renewable and Non-renewable resources

Stage:_____

Number of Decades	**Number of Non-Renewable resources (Black beans)**	**Number of Renewable resources (White beans)**	**_____% decrement/incremented in the energy consumption**	
			Equation	No. Seeds
1				
2				
3				
4				
5				

Source: Self Elaboration

2.3. Instrumentation, data collection and analysis

One of the instruments used in this study was based on a report made by the participants after executing the activity described in Section 3. The such report contained quantitative and qualitative data using graphics of energy used over time and a discussion of their results obtained from the three simulated stages.

Statgraphics Centurion XVIII software was used in the data analysis (Rojewski et al., 2012, Keselman et al., 1998, Rutherford, 2011), and One-way ANNOVA was employed to detect differences between the proposals in the three different stages and evaluate the effects of understanding the topic on engineering students. For this study, the dependent and independent variables were the number of total decades of each proposal and the periods, respectively. Subsequently, a post hoc test (least significant difference [LSD]) was used as a comparative measurement between the periods. The analysis of the proposals had reliability of α=0.05, which indicates good internal consistency.

Another instrument consisted of the application of a survey with ten items to each student, which contains statements that reflected the student's perception of the rhythm of energy consumption and the impact on the use of renewable and non-renewable energy.

3. Description of proposed strategy

Initially, participants of each period were divided into different teams. Each team had one bag with 100 beans. Each bag represented the energy consumption over time (100%), and the black and white beans represented 90% and 10% of non-renewable and renewable resources, respectively. This is based on current fossil fuel consumption reaching 90% in Mexico (Banco Mundial, 2023).

Based on (Robin, 2022), the narrative of this dynamic activity was as follows: participants from each team took turns to take out the specific number of beans (according to the variant in each stage) from the bag in a blind way to avoid choosing the colour. Each extract represents the rate of energy consumption in a decade. The number and colour of beans extracted are related to the simulated conditions: increments or decrements of total energy consumption and changes in the use of energy. These conditions are described in three stages:

a) Stage I: There are no changes in current energy consumption per decade; therefore, total energy consumption will be 100%. In order to represent this percentage, each participant removes ten beans from the bag without selecting them. Then the team takes note of each colour (Figure 1.1), and only returns the renewable beans to the bag. The participants continue until renewable beans are depleted and have to take the non-renewable beans in the last round. The team must plot the number of black and white beans as a function of the number of rounds. And afterwards, they will determine how many decades of total energy are used at the current rate.

b) Stage II: Two proposals as hypothetical situations were raised by the teacher under the same conditions.

1. An increment of 6% of total energy consumption per decade. Each participant now will extract a rate of 0.6 more beans per turn. For example:

– For 1st decade, ten beans are extracted from the bag due to it is the initial condition.
– For 2nd decade, 10.6 beans are extracted from the bag, which represents an increment of 6%. It is equivalent to 11 beans.
– For 3rd decade, considering the result obtained in the 2nd decade, 6% of total energy consumption is added. Therefore, 11.236 beans are extracted from the bag, which is equivalent to 11 beans.
– And so on.

The equation that represents this case is given by:

$$x = (10)(1.06)^{n-1} \quad (1)$$

where x is the number of extracted beans by round and n is the number of rounds.

2. A decrement of 2% of the total energy consumption per decade. For this case, each participant will extract a rate of 0.2 fewer beans per turn.

– For 1st decade, ten beans are extracted from the bag because that is the initial condition.
– For 2nd decade, 0.98 beans are extracted from the bag, which represents an increment of 2%. It is equivalent to ten beans.
– For 3rd decade, considering the result obtained in the 2nd decade, 2% of total energy consumption is reduced. Therefore, 9.604 beans are extracted from the bag, which is equivalent to ten.
– And so on.

The equation that represents this case is given by:

$$x = (10)(1.02)^{n-1} \quad (2)$$

where x is the number of extracted beans by round and n is the number of rounds.

c) Stage III: The participants propose two activities with different percentages based on the experience obtained in the first and second stages and the process is repeated. However, these proposals also may contain increase or decrease the consumption of renewable or non-renewable energy. For example, if a participant proposes a 5% increase in the consumption of renewable energy, 100% of the consumption is maintained, and only the amount corresponding to the proposed percentage of white beans will be added to the bag, keeping the amount of:

$$x_w = (10)(1.05)^{n-1} \qquad (3)$$

where n is the number of rounds and x_w is the total amount of white beans that must remain in the bag until they are extracted in the last rounds. Furthermore, if a participant proposes a decrease in consumption of non-renewable energy, then from the black beans extracted in each round, the proposed percentage amount per decade will be returned to the bag.

Finally, the participants from each team had to choose which of its proposals in Stage III could prolong more duration of non-renewable energy and discuss real forms of consumption to reach its purpose and obtain a result more sustainable.

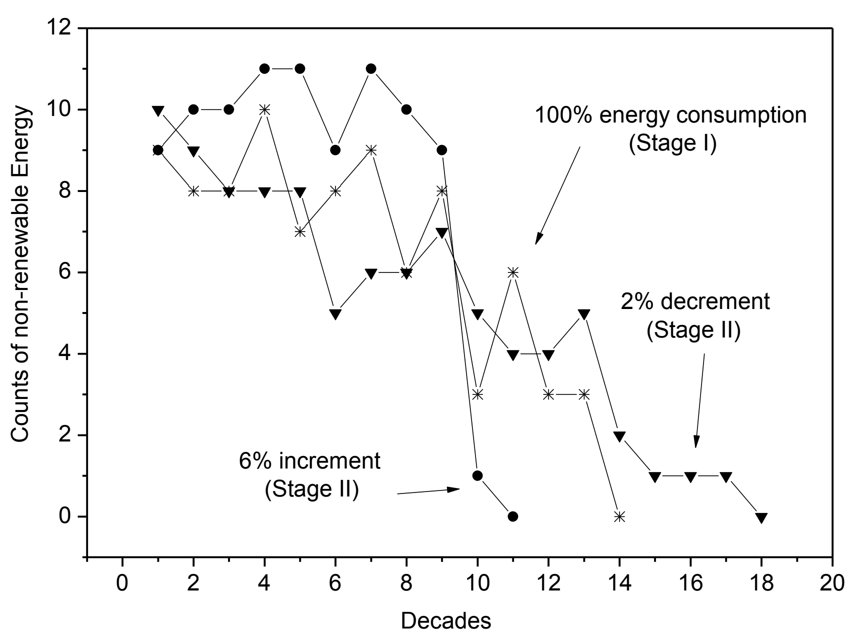
4. Survey results

4.1 Report results

As an example of the activity to be carried out in the participants' reports, Graph 4.1 shows the comparison of the graphs corresponding to stages I and II of the activity.

In Graph 4.1, it can be observed that the total duration of non-renewable energy was 14 rounds in stage I, which corresponds to the total energy consumption without increment or decrement; i.e., there are no changes in the energy current consumption per decade (100%). Such a result indicates that this current consumption rate of 90% and 10% of non-renewable and renewable energy, respectively, would last for 14 decades. In stage II, where there is an increment of 6% of energy demand, the duration of non-renewable energy was 11 decades, showing how this increment could limit non-renewable energy in 3 decades. In the case of a decrease in energy demand by 2%, the average reached values up to 18 decades, indicating that this strategy could be a solution possible to have a sustainable consumption of energy. The participants could deduce that an increment in energy consumption reduces the decades of use of renewable energy. On the other hand, a decrement in energy consumption increments the decades and the use of renewable energy.

Graph 4.1 Graphs of stages I and II of the activity



Source: Self Elaboration

Based on the reports' generated information, Table 4.1 contains the results of participants' proposals from Stage III, separated into three periods. It was found that most of the proposals made by students are based on extending total energy by decades changing energy consumption or using renewable energy, thus more than 14 decades of total energy duration were obtained. This result showed that participants deduced the effect of increasing and decreasing energy consumption on the increase or decrease of decades. In other words, an increment in energy consumption reduces the decades and use of renewable energy and vice-versa.

Table 4.1 Report results of participants' proposals from Stage III

Period	Teams	Proposal	Decades	Long-term sustainable	Teacher Conclusion
September 2020	1	-Increase the use of renewable energy by 10% per decade	17	Yes	They understand energy issues and sustainable needs.
		-A decrease in 5% demand energy	27	Yes	
	2	-Increase the use of renewable energy by 20% per decade	20	Yes*	They understand energy issues and sustainable needs.
		-Increase the use of renewable energy by 8% per decade	16	Yes	They understand energy issues and sustainable needs.
	3	-A decrease in 5% demand energy	25	Yes	They do not understand the problem beyond that non-renewable energy is depleted, they do not address measures to prevent it.
		-An increase in 5% demand energy	10	No	
	4	-Increase the use of renewable energy by 8% per decade	17	Yes	They understand energy issues and sustainable needs.
		-Increase the use of renewable energy by 5% per decade	19	Yes	
	5	-An increase in 8% demand energy	15	No	They understand the need for renewable energy, but don't sustainable needs.
		-Increase the use of renewable energy by 12% per decade	19	Yes*	
	6	-Increase the use of renewable energy by 30% per decade	25	Yes*	They understand energy issues and sustainable needs.
		-A decrease in 2% demand energy	17	Yes	
October 2021	1	-An increase in 15% demand energy	13	No	They understand the need for renewable energy, but don't sustainable needs. The conclusion does not show anything relevant, raise the need for renewable energy but point out that it must be fast and not something that increases with time.
		-Increase the use of renewable energy by 20% per decade	20	Yes*	
	2	-Increase the use of renewable energy by 20% per decade	18	Yes*	They understand the need for renewable energy, but don't sustainable needs. They conclude the problem and sustainable need, although it is out of proportion.
		-An increase in 12% demand energy	10	No	
	3	-Increase the use of renewable energy by 30 % per decade	23	Yes*	They partially understand the problem and propose sustainable measures.
		-A decrease in 20% demand energy	25	Yes	
	4	-Increase the use of renewable energy by 25% per decade	24	Yes*	There is an understanding of the problem, but with unrealistic proposals, although with a sustainable theme.
		-A decrease in 25% demand energy	21	Yes	
	5	-A decrease in 20% demand energy	23	Yes	The problem is not understood and has no consistency.
		-A decrease in 8% demand energy	22	Yes	
	6	-An increase in 6% demand energy	18	No	They understand the need for renewable energy, but don't sustainable needs. They understand the problem and sustainable needs
		-Increase the use of renewable energy by 10% per decade	19	Yes	

*Not real proposal

Source: Self Elaboration

Table 4.1 Report results of participants' proposals from Stage III (continuation)

Period	Teams	Proposal	Decades	Long-term sustainable	Teacher Conclusion
April 2022	1	-An increase in 5% demand energy	12	No	They do not understand the problem of the need for renewable energy, but understand sustainable strategies.
		-A decrease in 10% demand energy	16	Yes	
	2	-An increase in 4% demand energy	14	No	They partially understand the problem and propose sustainable measures.
		-An increase in 60% demand energy	8	No*	
	3	-An exponential increase in demand energy	6	Yes	They don't understand the rules. They seem to understand the dynamics and the problems, they point out the factors for sustainability and the factors that make it worse.
		-Increase the use of renewable energy by 1% per decade	15	No	
	4	-An increase in 8% demand energy	9	No	The problem and sustainable actions are understood, but not enough results are proposed
		-An increase in 2% demand energy	11	No	
	5	-Increase the use of renewable energy by 10% per decade	16	Yes	They understand the problem of the need for renewable energy, but do not understand sustainable strategies. The problem and the actions are understood, but not the dynamics and the proposals are not real.
		-An increase in 30% demand energy	14	No	
	6	-Increase the use of renewable energy by 20% per decade	17	Yes*	The problem and the actions are understood, but not the dynamics and the proposals are not real.
		-A decrease in 2% demand energy	15	Yes	

*Not real proposal

Source: Self Elaboration

According to the proposals presented by each team, participants based on two points: 1) the importance of using renewable energies and 2) the rational use of total energy consumption. In this context, the teacher's conclusions showed that not all students clearly understood the concepts, or they confused them. In this point, the activity could be reinforced by completing a questionnaire with the basic concepts and providing more examples.

4.2 Survey results

In order to understand the effectiveness of the activity described above, participants were surveyed with respect to the three different periods after performing the activity. Table 4.2 shows the survey questionnaire as affirmative responses.

Results of the survey showed that this dynamic activity seems to have a positive effect on the understanding of the concept of renewable energy. To both first questions, it was obtained percentages from 96.7% onward. With respect to the third and fourth questions, participants of the 2020 period showed the lowest percentage in creating awareness of the exhaustion of non-renewable sources and in the concept of energy sustainability after completing the activity. According to teacher observations, these participants did not show as much interest in the activity as in other periods.

About the fifth question, the study found that a participant of the three periods could understand the problem of the eventual exhaustion of fossil fuels with this activity. This result showed that the participants acquired a high level of consciousness in this topic. However, in the question of how changes in energy consumption affect the use of renewable and non-renewable resources, it was obtained a low percentage in the 2021 period with a 76.7%, followed by 2020 period (86.7%), and 2022 period (96.7%). It reveals that the participants failed in understanding fully the role of energy resources on energy consumption.

Table 4.2 Statistical description of the questionnaire

Item/Period	September 2020	October 2021	April 2022
	Percentage (%)		
1. Did you help this activity to understand the concept of renewable and non-renewable energy?	96.7	96.7	100
2. Did you think that create awareness of the depletion of non-renewable sources after doing the activity?	96.7	96.7	96.7
3. Did you increase awareness of the depletion of non-renewable sources after doing the activity?	86.7	90	90
4. Did you understand the concept of energy sustainability after doing the activity?	66.7	86.7	86.7
5. Did you understand the problems of eventual exhaustion of fossil fuels after doing the activity?	96.7	90	93.3
6. Did you understand how changes in energy consumption affect the use of renewable and non-renewable resources?	86.7	76.7	96.7
7. Did you understand the importance of optimizing the energetic resources after doing the activity?	86.7	86.7	90
8. Did you visualize the need to develop technology for using renewable resources after doing the activity?	100	93.3	96.7
9. Of the results obtained from activity, what type of strategy do you that could be more favourable nowadays?			
10. To reduce current energy consumption	46.7	63.3	50
11. To increase consumption of renewable energy	26.7	13.3	16.7
12. To reduce consumption of non-renewable energy	26.7	23.3	33.3
13. Do you think the proposal described in your activity report could be implemented in real life?	83.3	90	96.7

Source: Self Elaboration

Regarding the seventh and eighth questions, results were obtained with respect to the need to conserve current energy sources and develop new renewable resources. It was observed a direct impact on raising awareness of participants in the topic. From the three periods, the responses of participants were over 76%. Based on the participants' opinions on the ninth question; the most favourable type of strategy today, inconsistencies were found between participants' reports and the questionnaire. Firstly, most participants think that the best option is to reduce current energy consumption, 46.7% (2020 period), 63.3% (2021 period) and 50% (2022 period). While in the proposals of the activity, 33% (2020 period), 25% (2021 period) and 16.6% (2022 period) proposed strategies to reduce current energy consumption. When comparing these percentages with the proposals, their answer only is consistent in the 2020 period.

Secondly, the following option as the most favourable type of strategy today is to reduce consumption of non-renewable energy, 26.7% (2020 period), 23.3% (2021 period) and 33.3% (2022 period). In the proposals of the activity, no proposal was made regarding this response in the three periods. Finally, the third option as the most favourable type of strategy today is to increase the consumption of renewable energy, 26.7% (2020 period), 13.3% (2021 period) and 16.7% (2022 period). In the proposals of the activity, 50% (2020 period), 75% (2021 period) and 33% (2022 period) proposed that the best solution favourable is an increase in renewable energy. It indicated that the activity reinforces this point and clarifies the doubts of the participants on this topic.

According to the participants' opinions on the tenth question, more than 83% think that their proposals could be implemented in real life. It indicates that this activity may help to generate new proposals in the use of energy supply and their prolongation over the years. The interest of the participants in knowing the role of energy demand may be increased during their professional careers.

4.3 Statistic analysis

To evaluate the effect differences between the proposals in the three different stages and evaluate the effects of understanding the topic on engineering students, One-way ANNOVA test was performed using the results of Table 4.1 and the total of decades obtained as a result of the activity carried out by participants for each stage in the three different periods with a 95% confidence interval (α=0.05). One-way ANNOVA results are shown in Tables 4.3, 4.4 and 4.5.

Table 4.3 shows results for stage I (initial proposal), where the current energy consumption is 90% of non-renewable energy and 10% of renewable energy. In stage I, the null hypothesis is that all participants obtained the same knowledge for this stage of the activity carried out. As shown in Table 4.3, the p-value = 0.5803 obtained was higher than the p-value of 0.05 (α = 0.05). This means that there is no statistically significant difference between the proposals presented in all periods, and therefore, the assumption of homogeneity in the knowledge obtained by the participants in stage I was not violated. Thus, participants obtained same knowledge for this stage in the three periods.

Table 4.3 One-way ANNOVA analysis on the learning of participants stage I (n=18)

Source	SS	df	MS	F-value	P-value
Periods*	0.777778	2	0.388889	0.56*	0.5803
Error	10.3333	15	0.688889	-	-
Total	11.1111	17	-	-	-
* p > 0.05, a Stage I teacher proposal in 3 different periods.					

Source: Self Elaboration

Table 4.4 shows One-Way ANNOVA test for stage II (teacher proposal). There, one proposal was an increase of 6% of total energy consumption per decade and the other was decreased by 2%. In this case, the null hypothesis is that participants of the three different periods noted the effect of change in energy consumption in the number of decades, i.e., an increment in energy consumption reduces decades and limits the use of non-renewable energy and vice-versa. Table 4.4 shows a p-value = 0.9397, which is higher than the p-value = 0.05; that is an allowable error (α= 0.05) (Rojewski et al., 2012). This means that there is no statistically significant difference in the three different periods of stage II, indicating that most participants observed the relationship between increasing and decreasing energy consumption, duration in decades, and use of renewable energy, as shown in Graph 4.1.

Table 4.4 One-way ANNOVA analysis on the learning of participants stage II (n=18)

Source	SS	df	MS	F-value	P-value
Periods*	2.33333	2	1.16667	0.06*	0.9397
Error	280.167	15	18.6778	-	-
Total	282.5	17	-	-	-
* p > 0.05, a Stage II teacher proposal in 3 different periods.					

Source: Self Elaboration

Table 4.5 shows One-Way ANNOVA test results for stage III, where the proposals made were of all participants. In this case, the null hypothesis was based on the fact of participants could define their own proposals about energy consumption by decade regarding the knowledge acquired from previous stages; p-value = 0.0006 obtained in Table 4.5 was lower than 0.05, indicating that there is a significant difference between the results of proposals. It points out that not all the participants were able to elaborate their proposals about energy consumption by decade, even though they observed a relationship established in stage II.

Table 4.5 One-way ANNOVA analysis on the learning of participants stage III (n=36)

Source	SS	df	MS	F-value	P-value	LSD*
Periods*	349.389	2	174.694	9.44*	0.0006	P1 = P2 P1 $\neq$ P3 P2 $\neq$ P3
Error	610.917	33	18.5126	-	-	
Total	960.306	35	-	-	-	
* p > 0.05, a Stage II teacher proposal in 3 different periods, wrong adjustment for multiple comparisons: Least Significant Difference						

Source: Self Elaboration

One-way ANNOVA test results for this stage indicate there were differences between the participants' knowledge without knowing the specific periods where they differ, therefore a One-Way ANNOVA post hoc test was performed. Results using LSD analysis showed that there was not a significant difference between both periods 2020 and 2021.

However, there is a significant difference in LSD with respect to the period 2022. Based on the results of Table 4.1, it was observed that basic concepts or communication between team members were not clear enough. Most of the proposals in the period 2022 do the energy have a duration lower than the proposal with respect to current consumption, which is not concordant with the aim of the activity.

It was also found that 50% of the proposals on the type of strategy more favourable nowadays during the 2022 period was based on an increase in the demand for energy. These differ from the objectives of the activity. In other words, participants misunderstood the concepts of energy consumption, because there was a change in the execution of activity in the year 2022. It passed from face-to-face to virtual mode to understand the difficulties in the teaching learning process.

5. Conclusions

A validation of the effects of a dynamic activity to teach the concepts of renewable energy to engineering students in Mexico was described and evaluated. This research used a One-Way ANNOVA test determined differences between the proposals of teachers and participants and interpreted the level of participants' knowledge acquired, and a survey to examine the effects of understanding the topic and detect discrepancies between directed questions and their proposals. Evidence from previous research supports the following conclusions:

1. This study has shown that the dynamic activity has a positive impact on students' understanding of the concepts of renewable energy.

2. The application of this dynamic activity allows the teacher to evaluate the level of knowledge of the students, as well as their difficulties in understanding concepts related to renewable energy.

3. The effectiveness of this dynamic activity is evident in participants, especially when participants interact face to face.

4. The communication face to face between team members is a key factor for learning achievement and the reduction of misconceptions in the participants.

5. The dynamic activity in virtual mode impacts negatively the performance of participants and increases the confusion of concepts of the renewable energy topic.

6. It was observed that the dynamic activity offers a better panorama of energy substantively.

7. It was found that students created awareness in the topic of renewable energy, mainly in the current rate of energy consumption.

8. It is suggested the teacher's feedback or the application of a test to correct any deficiencies or misunderstandings in the topic.

6. Credit author statement

Laura Andrea, Pérez: Methodology, Software, Writing - Review & Editing, Lizbeth Salgado: Investigation, Writing - Original Draft, Carlos Álvarez: Conceptualization, Methodology, Writing - Review & Editing, Supervision

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