***Digital Learning Object Based on Transition Design Methodology to
Promote the Energy Efficiency Culture:
An Interdisciplinary Development for STEAM Education***

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Abstract
This paper presents the design, development, and quantitative and qualitative evaluations of a digital learning object based on the Transition Design methodology and the ISO-50001 standard (i.e., Energy Management System). To clarify, Transition Design addresses complex problems, called wicked problems, such as climate change, the global pandemic, and lack of access to affordable education, among others. In particular, the problem addressed in this paper is the lack of knowledge of general and standardized aspects related to energy efficiency in the secondary education curriculum design & development in Mexico. Therefore, obtaining good results in the energy efficiency context turns out to be very complicated, since there is no standard framework, and the activities or learning objects used, are not generally appropriate to the expected learning outcomes. In this way, through social immersion, focus groups, creativity techniques, and digital design tools, a market study was carried out considering a sample of 208 students distributed into 6 groups from different subjects, where the subjects are related to natural & exact sciences and social sciences & humanities. The aforementioned is for assessing the student's learning styles to determine the most adequate digital learning object for them. As a result, a digital learning object was developed in an interdisciplinary manner considering the Kolb learning styles., i.e., concrete experience, reflective observation, abstract conceptualization, and active experimentation. Finally, this project has implications for the future development of the secondary education curriculum, but the learning object can also be adapted to existing educational programs and models.

Keywords: Digital Learning Object, Energy Efficiency, Interdisciplinary Development

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Introduction

Nowadays, there are many wicked problems around the world, such as extreme poverty, climate change, among others. These problems cannot be approached like traditional problems, that is, in a linear way (Lönngren and van Poeck, 2021). Among those wicked problems is environmental pollution related to energy efficiency in society. Considering the above, the energy efficiency culture must be strengthened in all sectors of society, mainly in educational centers of different levels, to strengthen soft and hard skills regarding the efficient use of energy resources. In support of the above, there are digital learning objects (DLO) that you can help to promote the energy efficiency culture on a Science, Technology, Engineering, Arts, and Mathematics (STEAM) education framework. In this way, this article shows the design of the DLO based on the transition design methodology to address this wicked problem (Cabero-Almenara and Palacios-Rodríguez, 2021).

Theoretical framework

Standard ISO-50001

ISO-50001 is an international standard developed by the International Organization for Standardization (ISO). This standard is of voluntary application, that is, companies, organizations, and institutions are not obliged to comply with them, but they can promote their compliance and consideration. In general, ISO-50001 provides organizations with an internationally recognized and approved reference framework to manage and improve energy performance. The standard is broad, but in particular, it covers the following, 1) the efficient use of energy in all activities of an organization, 2) the measurement, documentation, and reporting of energy uses, 3) the design and practices procurement for equipment, systems, and processes that are energy efficient, 4) the development of an energy management plan, among other factors that affect energy efficiency. In this way, the adoption of ISO-50001 by the organization allows reducing the carbon footprint of the products and services offered, which is part of sustainable business development. As mentioned, although the standard is indeed made up of many stages and sub-stages, it is not the objective of this document to explain it in detail. Therefore, the stages and sub-stages that make up the standard will be disclosed within the DOL, which are based on the Deming cycle, Do-Check-Act-Plan (Marimon and Casadesús, 2017).

Learning styles

David A. Kolb's learning styles model states that learning is based on experimentation and processing of the information that is received. This model contemplates four stages for optimal information processing, which are: a) concrete experiences (feelings); b) reflective observation (watching); c) abstract conceptualization (thinking); and d) experimentation (do). People tend to focus on one of these phases, which is preferable in terms of learning. Therefore, four learning styles are established according to how they prefer to process the information received. It is classified as 1) Divergent, associated with experience and observation; 2) Convergent, based on abstract conceptualization and active experimentation; 3) Assimilators, related to abstract conceptualization and reflective observation; and 4) Accommodators, based on concrete experience and active experimentation (Newton and Wang, 2022).

Transitional design methodology

The transitional design is a methodology that allows for solving systems and complex problems such as climate change, crime, forced migration, loss of biodiversity, poverty, and water security. These problems are challenging because: 1) they involve multiple stakeholders with conflicting agendas; 2) straddle disciplinary boundaries; 3) are ill-defined and stakeholders rarely share an understanding of the problem; 4) the problem is continually changing and evolving; 5) problems exist at multiple levels of scale and are interdependent and interconnected; 6) any intervention (attempted solution) in one part of the system, ramifies elsewhere in unpredictable ways; 7) interventions take a long time to evaluate, and problems, a long time to resolve (Costa and Irwin, 2018).

Methodology

Research of teaching resources

To optimize project resources and generate an updated and easily accessible learning object for students, it was decided to use an online platform for its creation. In this way, an investigation of different digital platforms, that could be used for the development of the learning object, was carried out. Below is a compilation of the most relevant platforms found online. The advantages and disadvantages of each one were considered to determine the platform that was selected for the creation of the learning object.

Open edX

It is an open-source digital learning platform for creating, providing, and analyzing online courses developed by Harvard University and the Massachusetts Institute of Technology, currently managed by the non-profit organization, The Center for Re-Imagining Learning, formerly known as edX Inc. (Open edX, 2023). The advantages of Open edX are, 1) It is a free platform, 2) It allows you to create units, sections, and discussions and has a wide variety of reagent options, and 3) It handles certificates, exams, and study activities. While the disadvantages are, 1) For the more advanced aspects of the course you need knowledge of the HTML programming language and 2) customization in terms of design is limited.

Google Classroom

It is the tool that Google offers for education, it allows you to manage a classroom online and collaboratively. The platform is linked to the user's Gmail account, which allows the use of different Google extensions, such as creating documents, working simultaneously, generating online meetings, and sharing information in different formats (Google, 2023). The advantages of Google Classroom are, 1) It is very easy and intuitive to use, 2) It is a platform with recognition and positioning, 3) It allows you to create exams, surveys, announcements, and units, and 4) It shows graphs with the results of the exams and surveys. While the disadvantages are, 1) The types of reagents are limited, 2) It is currently not considered a novel platform, and 3) The freedom of customization of the design is of an intermediate level.

Moodle

It is an online learning platform created to provide educators and students with a safe tool for the generation of learning environments that can be personalized (Moodle, 2022). The

advantages of Moodle are, 1) It offers a wide range of activities: quizzes, surveys, wikis, glossaries, and more, 2) Its interface and design are nice and modern, and 3) It is constantly updated. While the downsides are, 1) Moodle is free to download, but server hosting costs extra, and with the free plan you have to find a provider or contract from the same page, and 2) Being open source, knowledge of HTML is required to perform certain functions.

iSpring Learn

iSpring Learn is an LMS aimed primarily at companies that want to train their employees. It works as a simple corporate platform for the creation of advanced courses where administrators can publish content, generate activities and track the results of their employees (ispring, 2023). The advantages of iSpring Learn are, 1) Its interface and design are friendly, modern, and intuitive, 2) It allows students to be awarded points and rewards for correctly completing an activity or unit, and 3) It is updated. While the disadvantages are 1) The yearly subscription depends on the number of active learners and starts from $3.66/user/month for up to 100 active users, and 3) It is mainly aimed at businesses.

Curriki

It is a non-profit organization founded in 2004 by Sun Microsystems, which manages an online learning platform focused on providing a wide range of interactive activities and revolutionizing online learning (Curriki 2022). The advantages of Curriki are, 1) Clean, friendly, and intuitive design for the student, 2) It is completely free, and 3) It has a great variety of types of activities. While the disadvantages are, 1) It can be linked with other LMS like Google, but it doesn't return results, and 2) The creation of activities is not very intuitive, especially the ones with a higher level of complexity and length.

Other very complete platforms were found in terms of an LMS. However, they were discarded due to their high costs, which were around $29 per month. Some of the platforms were Learndash and Appsembler. Considering the analysis of the different online platforms found, it was decided to use Curriki for the development of the Learning Object due to its large number of interactive reagents, interface, and updating.

Classification of Curriki teaching activities

Considering the Curriki platform, a classification of the activities was carried out according to Kolb's learning styles; adapter, divergent, assimilator, and convergent. Likewise, the activities that could function as a review for the students as well as to present and conclude the information seen in each unit were identified.

Accommodators

In this learning style, the student performs better by doing things kinesthetically and engaging in new experiences (Poch, 2023). After an analysis, it was determined that the activities related to this learning style considering the Curriki platform are:

- ✓ Branching Escenario: The student will experience different scenarios according to the answers they choose.
- ✓ Drag and Drop: Identify and drag the concepts with their corresponding images.
- ✓ Collage: Composition of different images on one or several themes.

- ✓ Guess the Answer: The student will have to identify the correct answer to the question posed.
- ✓ Image Hotspot: It will be possible to navigate in an image with interactive hotspots that will contain information, images, or a video.
- ✓ Interactive Book: A digital book with animations and transitions.
- ✓ Virtual Tour: It allows to navigate in a virtual space with explanations, videos, sound, and presumed interactions.
- ✓ Personality Quiz: Multiple choice quiz returns a result depending on the options selected.

Divergent

The strongest point of people who present this learning style is their imaginative capacity (Poch, 2023). After an analysis, it was determined that the activities related to this learning style considering the Curriki platform are:

- ✓ Image Juxtaposition: Overlapping images that can be displayed interactively through a slider.
- ✓ Agamotto: Image transition.
- ✓ Find the Hotspot: Find the correct option that completes the image.
- ✓ Flash Cards: Cards with pictures and open questions.
- ✓ Image Pairing: Select the corresponding images.
- ✓ Immersive Presentation: Presentation with interactive elements.
- ✓ Mark the Words: Underline the requested concepts of a text.
- ✓ Timeline: Graphic representation of a chronological sequence of events.
- ✓ Word Find: Find and mark certain words within a series of letters arranged in columns and rows.

Assimilators

People with this type of learning are characterized by their ability to create theoretical models (Poch, 2023). After an analysis, it was determined that the activities related to this learning style considering the Curriki platform are:

- ✓ Column Layout: Display of information in the form of columns.
- ✓ Dialog Cards: Virtual cards with information, sound, and images.
- ✓ Documentation Tool: Add a document.
- ✓ Questionnaire: Open-ended and multiple-choice question series.
- ✓ Quiz: Questionnaire with different types of reagents.
- ✓ Essay: The student generates his argued opinion based on a question.
- ✓ Image Slider: Display of an image series with description.
- ✓ Immersive Reader: Reading with audio and other immersive elements.
- ✓ True & False: Choose whether the statement is true or false.

Convergent

They stand out for learning through the practical application of ideas (Poch, 2023). After an analysis, it was determined that the activities related to this learning style considering the Curriki platform are:

✓ Advanced Fill in the Blanks: Select the correct answer from a series of options.
✓ Chart: Answer questions based on graphs.
✓ Drag Text: Put the words that correspond to the concept.
✓ Fill in the Blanks: Complete the sentence with the correct answers.
✓ Image Sequencing: Image series.
✓ Interactive Video: Video with questions and presentation of concepts.
✓ Memory Game: memory game with cards.
✓ Single Choice Set: Multiple choice quiz with only one correct answer.

Review activities such as Accordion, Summary, Column Layout, Course Presentation, and Frame Embedded were also identified.

Survey

To find out how students learn at the upper secondary level, a survey was developed with the Google Forms digital tool consisting of 13 questions/statements related to learning styles and 4 according to the user's personal information, such as age, gender, level academic and sector, to use it for statistics. The sample size was 208 high school students from 6 groups from different subjects, where the subjects are related to natural & exact sciences and social sciences & humanities. Multiple choice questions were implemented for personal data, and the Likert scale was for questions related to learning style. The Likert scale was categorized and quantified as follows: 1 = Strongly disagree, 2 = Disagree, 3 = Neutral, 4 = Agree, and 5 = Strongly agree. The survey questions were the following:

A. Adapters or Accommodators
  S1. You prefer to implement solutions, so you take risks and are open to options. Also, you prefer teamwork.
  S2. You are comfortable with the need to obtain the necessary resources to achieve your goals related to a particular project.
  S3. You prefer multitasking, that is, carrying out several activities simultaneously.

B. Convergent
  S4. You need the practical application of ideas to test theories or solve problems.
  S5. You lose yourself when there are many alternatives.
  S6. You are exceptional in situations where there is only one way to be resolved.

C. Divergent
  S7. You enjoy analyzing (critiquing) problems as a whole and working with other people (multiplicity).
  S8. You are empathetic (open-minded), emotional, and witty (creative).
  S9. You generate a large number of ideas (brainstorming), that is, you are very creative.

D. Assimilators
  S10. You participate in the creation of theoretical models and the clear definition of problems.
  S11. You are more interested in projects related to abstract ideas (exact and natural sciences) than those projects directly related to people (social sciences and humanities).
  S12. You prefer individual work to group work.

Results

Statistics of Styles and learning objects

The results of the survey are shown in Table 1. In general, it is concluded that learning style C (Divergent) is the predominant one in the analyzed sample. In particular, the average value and standard deviation of this learning style are 3.96 and 0.96, respectively. While the least predominant learning style is D (Assimilator), with an average value of 3.42 and a standard deviation of 1.12. Now, considering the predominant learning style and their statements, the S8 has the best score, an average value of 4.33, and a standard deviation of 0.84. In this way, the results shown in Table 1 allow for establishing the assignment rule for the didactic activities in proportion to the learning styles qualification. That is to say, the learning object proposed in this research will give priority to learning activities related to learning style C, then to A and B (because they have similar expected values and standard deviation), and finally to learning style learning D.

		Average (S)	S.D (S)	Average (LS)	S.D (LS)	Ranking (A)
A Adapters or Accommodators	S1	3.78	0.99	3.62	1.05	2
	S2	4.01	0.90			
	S3	3.08	1.27			
B Convergent	S4	3.96	0.99	3.60	1.05	3
	S5	3.08	1.22			
	S6	3.75	0.94			
C Divergent	S7	3.77	1.06	3.96	0.96	1
	S8	4.33	0.84			
	S9	3.78	0.97			
D Assimilators	S10	3.58	0.94	3.42	1.12	4
	S11	3.44	1.21			
	S12	3.25	1.20			

Table 1. Statistics of Styles and learning objects.

Digital learning object development in Curriki

Below is evidence of the development of the DLO on the Curriki platform. It is essential to mention that the DLO was developed in Spanish. Figure 1 shows the sections of the DLO. Figure 2 shows the learning activities from Section 1, Introduction. Regarding the learning activities used, the results of Table 1 and the classification of Curriki's learning activities based on Kolb's learning styles were considered.

Figure 1: Digital learning object structure in Curriki platform.

Figure 2: Didactic elements of Section 1.

Figure 3: Example of learning activity as a review of Section 1.

Figure 3 shows an example of a review activity for Section 1. In fact, each section of the DOL consists of review and assessment activities.

Evaluation of the Digital Learning Object

An evaluation of the Digital Learning Object was carried out with the participation of 21 students. In general, the figures in this section show the distribution of the responses for each parameter evaluated. In particular, the average value of each parameter was: 1) The didactic resources used are attractive (4.19), 2) The technical information is understandable (3.9), 3) The presentation of the information is correctly organized (4.09), 4) The digital tool allowed me to recognize the general elements of the ISO-50001 standard, referring to energy management (3.71) and, 5) The digital tool helped me to better understand energy efficiency issues and methodology to address real problems in the industrial sector (3.71).
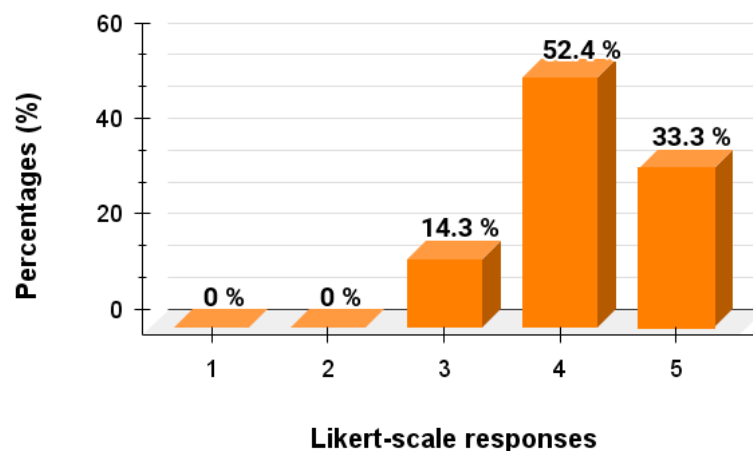

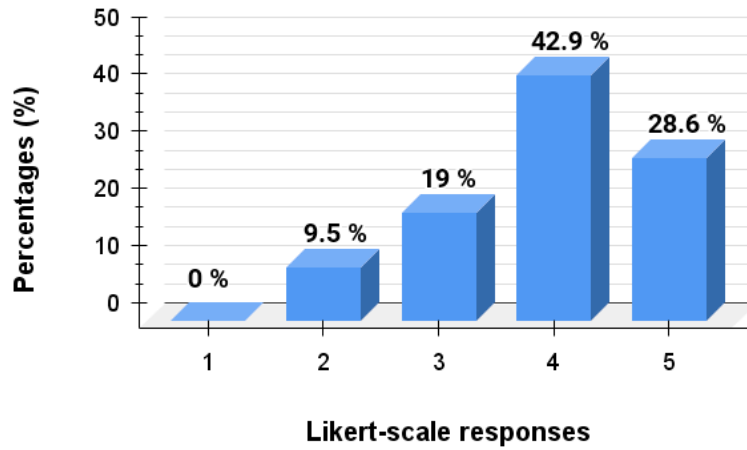Figure 4: Results of Parameter 1, The didactic resources used are attractive.

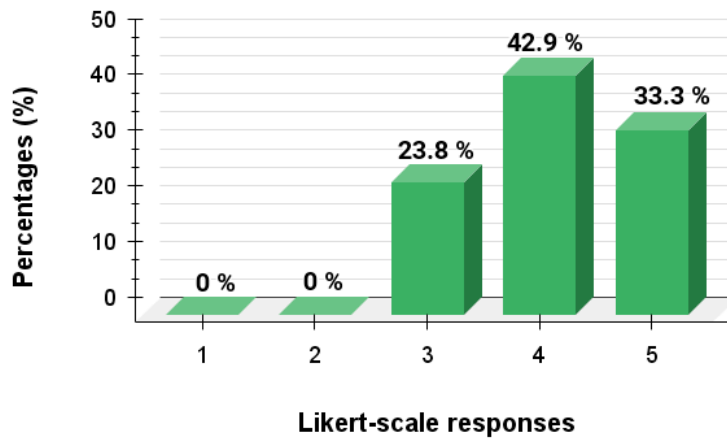Figure 5: Results of Parameter 2, The technical information is understandable.

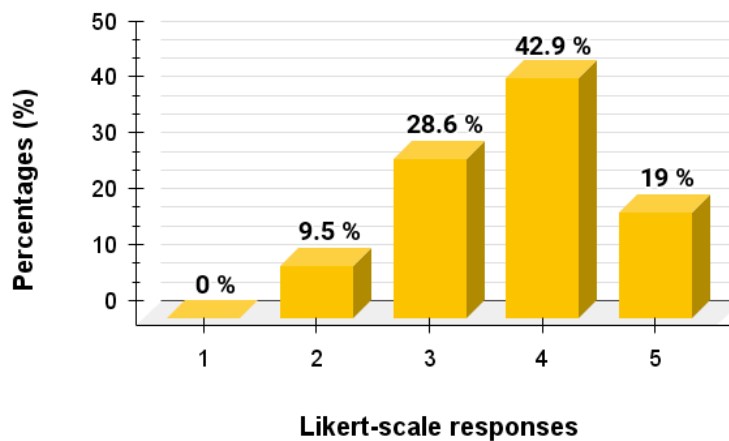Figure 6: Results of Parameter 3, The presentation of the information is correctly organized.

Figure 7: Results of Parameter 4, The digital tool allowed me to recognize the general elements of the ISO-50001 standard, referring to energy management.
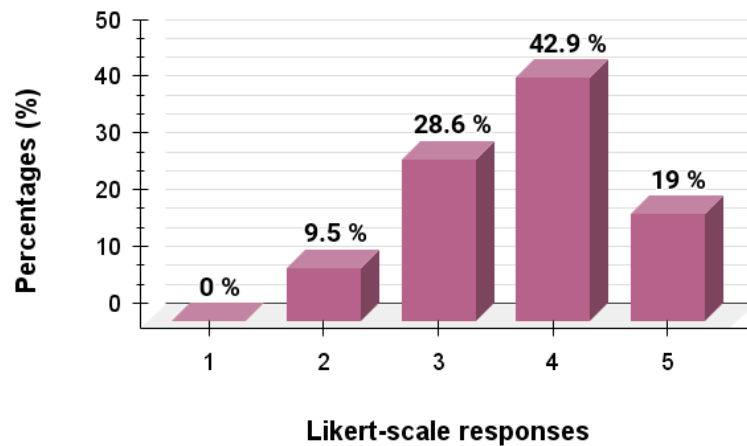
Figure 8: Results of Parameter 5, The digital tool helped me to better understand energy efficiency issues and methodology to address real problems in the industrial sector.

Conclusions

The developed Digital Learning Object has adequate ratings, generally between 4 and 5, on the Likert scale. Also, the Digital Learning Object presents some improvement aspects, mainly related to the presentation of the technical information of the ISO-50001 standard. Some questions for further investigation are: What learning activities improve the DLO assessment? What is the validity period of the DLO? What is the evaluation of DLO in the public sector?

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