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Design of a Python programming course by big ideas with a STEM approach

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Abstract*– Educational programs for migrants in Science, Technology, Engineering, and Mathematics (STEM) have traditionally been offered to adults, to facilitate their social and labor insertion. However, migrant children and youth have been made invisible, ignoring the effects of migration on their educational processes. The funds of knowledge acquired by these children and young people during their migratory trajectory have not been taken advantage of in the countries of destination. In this context, this article presents the design of a Python programming course by big ideas approach for Venezuelan migrant children and youth in Colombia, Mexico, and Peru. The instructional design with a big ideas approach is followed to define three big ideas with their respective learning objectives, teaching methodologies, and evaluation. An online and hybrid course is designed, called "First Steps of Migrants in Python with STEM Approach" which seeks to provide basic Python programming concepts and tools to develop computer programs. It is expected to develop enduring understandings focused on the development of technological projects with a STEM approach that uses computational thinking to enable migrant children and youth to solve everyday problems during their migration path.

Keywords*-- STEM, curricular design, migrants, big ideas, blearning.

I. INTRODUCTION

Blended learning (bLearning) combines face-to-face and virtual learning, understanding the face-to-face modality as the development of training processes in facilities where teachers and students interact in person. These physical facilities offer an ecosystem of services and physical and human resources that are ideal for offering quality education. However, educational institutions are expanding to reach different audiences and compete nationally and internationally, which confronts them in the dichotomy of quality and efficiency [1]. This has raised the need to design and implement new learning modalities that can complement and even replace the face-to-face modality, as is the case of the hybrid modality or bLearning [2] and the virtual or eLearning modality [3]. In this context, a Python programming course was designed for Latin American migrant children and youth called "First Steps for Migrants in Python with a STEM Approach". For this purpose, different modalities were evaluated to select the most appropriate one (see Figure 1), whether face-to-face, distance, virtual, or hybrid, their definitions are neither unique nor equivalent [4], although there is a consensus to improve coverage and guarantee quality [5].

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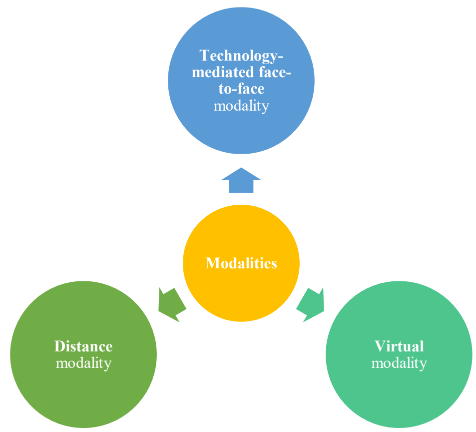

Fig. 1 Course modalities.

First, the technology-mediated face-to-face modality uses digital technologies to redesign the interactions between students, teachers, and content. This modality is also called face-to-face education enriched with digital technologies [6], which allows attending non-face-to-face audiences, guaranteeing coverage but not necessarily quality [1] since certain principles and procedures previously established by educational and accreditation authorities must be followed to comply with quality standards [5]. In addition, this modality simplifies educational processes and makes access to educational resources more flexible, but it is not adapted to the migratory trajectory of migrants because it requires face-to-face attendance in physical facilities to meet quality requirements.

Secondly, the distance modality seeks to improve coverage while taking care of quality. However, it focuses on content, through physical and audiovisual resources that include occasional interactions with tutors in physical facilities geographically distributed by regions. In this modality, digital technologies allow the design and implementation of virtual learning environments, which move the physical campus to the virtual campus, where synchronous and asynchronous interactions are included [7]. In this modality, quality standards must be complied with before the educational and accreditation authorities to differentiate it from other modalities and avoid confusion among them [8]. However, the migrant population would not be able to access distance education, since it is required to attend specific educational centers located in locations other than the migratory routes.

Thirdly, the virtual modality seeks that the interaction between students, teachers, and content is mediated by digital technologies and evidences a transformation of the educational process. Without the educational transformation, it is called online modality, and with the transformation, it is called virtual modality because digital technologies are used for the design and implementation of virtual learning environments that promote the transformation of the educational process [9]. This modality implies technological requirements such as an Internet connection and an electronic device to access the virtual campus, so a more flexible modality should be considered for migrants, allowing them to connect sporadically to the Internet during their transit through the migratory route.

Finally, the hybrid modality represents an academic load that mixes activities between face-to-face and virtual classrooms, together with the student's autonomous spaces. The academic load is estimated by calculating the percentage of the contents offered on-site and online. Thus, face-to-face courses offer online between 0 and 29% of the content, hybrid courses offer online between 30% and 79% of the content, and virtual courses offer online at least 80% of the educational content [10].

II. Methodology

This research seeks to align the research approach, with the research question and the research method [11]. For this reason, an approach, a research question, and a research method that were aligned were defined, in this case, a hermeneutic approach aligned with a question related to understanding and a qualitative method.

The research approach is hermeneutic, meaning that this research seeks to relate the understanding of the phenomenon studied, in this case, the instructional design by big ideas of a Python programming course for Venezuelan migrant children and youth, with its subsequent interpretation of the results obtained [12]. This approach does not study the representativeness of the results, but rather the depth of each of the students' cases in the context of their migratory trajectories that seek to be interpreted through the designed course.

Considering that the approach is hermeneutic, a research question related to understanding is proposed. The question related to understanding allows interpreting the results obtained from the course, to study its effects through the categories of analysis oriented by the research question. The research question is defined as how to design a Python programming course for Venezuelan migrants in Colombia, Mexico, and Peru from the big ideas approach in hybrid mode?

The procedure (see Figure 2) to answer the research question consisted of adapting the Big Ideas course design proposed by Galvis [13]. This curriculum design was adapted to the STEM approach proposed by Sanchez, Ramirez, and Herrera [14], to integrate STEM disciplines, as well as to promote the development of STEM skills and take advantage of its benefits in the implementation of inclusive classrooms for migrants.

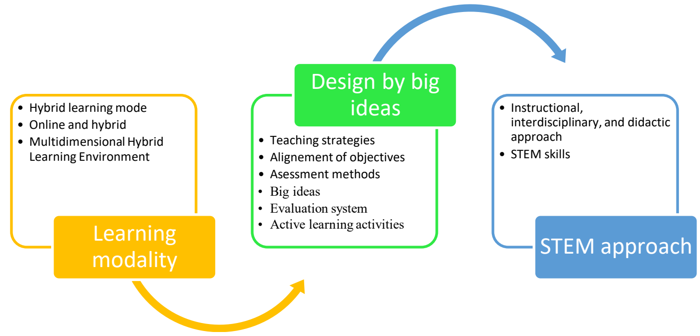

Fig. 2 Procedure.

III. Results

The final design follows the learning modality, the design by big ideas, and the STEM approach.

A. *Learning modality*

The learning modality can be a Hybrid learning mode, Online and hybrid course, and Multidimensional Hybrid Learning Environment (HLE).

Hybrid learning mode

The course was designed in a hybrid learning modality (bLearning), whose definition in the literature is diverse [4], but the consensus is to define it as a combined modality between the traditional (face-to-face) and electronic (virtual) learning systems [15]. However, it is necessary to determine the category of the course mediated by digital technologies.

In this sense, the characteristics of the hybrid modality must be guaranteed in the learning environment, understanding this environment as the set of conditions that allow one to understand the learning activities [16]. Therefore, it is expected that the learning environment of the hybrid mode course will include the bimodal space-time combination, the combination of which "promotes learning and its application" [4], to complement face-to-face instruction with digitally mediated instruction [17].

The course includes the five key elements of the hybrid learning modality (see Table I), such as face-to-face events, online content, collaborative environments, formative and summative assessments, and reference materials [18]. The face-to-face events are led by the teacher to generate motivation and satisfaction in their migrant students to attend face-to-face lectures and computational practices. Online content includes the learning path and guidebook, is accessible anytime, anywhere, and adaptable to the learning styles of migrant students. Online workshops and group forums promote collaborative environments that encourage student-student and student-teacher interaction. Learning activities include formative and summative assessments and reference materials provide support and in-depth content.

TABLE I

COURSE ELEMENTS IN HYBRID MODE

Hybrid course elements	
On-site events	Masterclasses and computational practices
Online content	Learning Path and Guidebook
Collaborative environments	Workshops and online group forums
Formative evaluations	Learning activities
Reference materials	Supporting content

Online and hybrid course

Courses have been categorized into hybrid learning modalities with different instructional methods. Mayadas and collaborators propose 7 categories of courses that combine face-to-face and virtual modalities.

The first category is for face-to-face classroom courses, whose activities are organized to be developed in the classroom; the second category of synchronous and distributed course, where digital technologies are used to extend remotely and in real-time the activities; the third category of technology-enriched course, where online activities complement the face-to-face classes without diminishing the classroom sessions; the fourth category of classroom and hybrid course, which mixes online activities with face-to-face classes, replacing a large percentage but not all of the face-to-face sessions; the fourth category of classroom and hybrid course, which mixes online activities with face-to-face classes, replacing a large percentage but not all face-to-face sessions; the fifth category of online and hybrid course, whose online activities are mixed with few face-to-face classes; the sixth category of online course has all online activities without face-to-face classes; and the seventh category of flexible-mode course with different instructional methods of the student's choice [19].

Considering these categories, the course is classified in the online and hybrid course categories, due to the inclusion of mostly online activities with some face-to-face activities. The course in this online and hybrid modality allows face-to-face and online learning actions [17], but the learning environment is not limited to what takes place in the classroom (Classroom Learning Environment - PLA) or the virtual classroom (Virtual Learning Environment - VLE) but is complemented with activities in autonomous learning spaces [20].

Multidimensional Hybrid Learning Environment (HLE)

The course is not only intended to be in hybrid learning mode using the virtual (AVA), face-to-face (APA), and autonomous environment but also to be developed in hybrid transformational mode, promoting the transformation of the educational process, including the 7 dimensions that affect the act of learning in Hybrid Learning Environments (HLE) [21].

The 7 dimensions for multidimensional AHA (see Figure 3) are the first dimension of spaces for interaction whether face-to-face or distance; the second dimension of times for interaction whether synchronous or asynchronous; the third pedagogical dimension whether conventional or inverted pedagogy; the fourth dimension of role in the teaching-learning process of the teacher, the student, and the stakeholders; the fifth dimension of means to reach knowledge such as expository, active or interactive means; the sixth dimension of learning experiences (formal, non-formal and informal); and the seventh dimension of learning environments (virtual or physical classroom) [9].

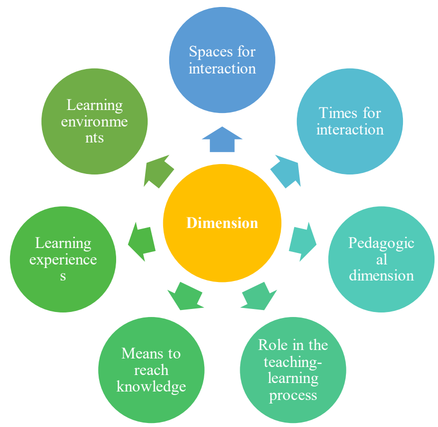

Fig. 3 Dimensions for multidimensional AHA.

Therefore, the course is designed in a transformative hybrid modality in a multidimensional Hybrid Learning Environment, which integrates seemingly opposing approaches such as face-to-face and virtual learning experiences, directed and self-directed learning to achieve personal and institutional learning goals [22].

B. Design by big ideas

The curricular design of course includes the general design, the specific design, and the STEM approach.

General course design

The course "First migrant steps in Python with STEM approach", is a course aimed at migrant children and youth between 10 and 17 years old, with a duration of 10 days, for 30 hours in total in which they will be taught daily synchronous classes of 2 hours and 1 asynchronous hour of daily autonomous work, during which they will learn STEM programming in Python (see Table II).

TABLE II

PRESENTATION OF THE COURSE

Dedication	The course requires a total of 30 hours over 10 days, with 2 synchronous hours and 1 asynchronous hour per day.
Description	You will learn different data structures such as lists, dictionaries, tuples, and arrays, as well as file handling, to apply these data structures to everyday solutions.
Purpose	This course aims to provide basic Python programming concepts and tools to solve everyday problems by developing computer programs.
To whom it is addressed	The course is aimed at children and young migrants between the ages of 10 and 17 who are interested in learning how to program in Python.
Modality	Online and hybrid course

Rules	Each student participates from wherever he/she wants using electronic devices with internet access, at his/her own pace, but within the time limits proposed for each activity of each unit.

The course has a back-to-front instructional design that uses learning for understanding [23], with 3 steps from what and why to learn, followed by how to know it was achieved, and ending in how and with what to do it. These three steps allow the alignment of objectives, assessment methods, and teaching strategies (see Figure 4). In this sense, Palmer also proposes a back-to-front instructional design, which involves the factors of the curricular environment to guide what is of interest to learn, focusing on learning goals to give meaning to learning and are the basis of the learning assessment system that is articulated with the learning activities, which together promote active learning.

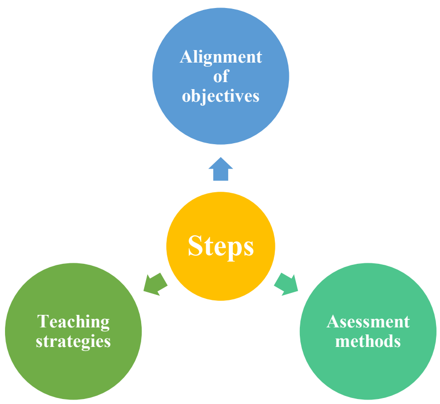

Fig. 4 Steps of general course design.

Specific course design for big ideas

The course was designed following the big ideas instructional design approach proposed by Galvis and Palmer, in 3 stages of macro design at the course level (see Figure 5), a first stage that defines the big ideas, a second stage that establishes the evaluation system, and a third stage that determines the active learning activities measured by digital technologies [9], [24].

Fig. 5 Steps of specific course design.

The course structure includes the concepts per unit (see Table III), the learning objectives and outcomes per unit (see Tables IV and V), the teaching methodologies (see Table VI), and the learning assessment (see Table VII). The first stage of defining the big ideas allows the identification of a big idea for each unit, from learning to understanding these big ideas are the conceptual framework of the concepts that are important to know and use in a specific domain [25]. Concepts per unit are the statements that allow the student to move from "not knowing" to "knowing" the knowledge required to demonstrate the learning objectives of the unit.

The first big idea (GI1) of Unit 1 describes what is expected from the context analysis, i.e. the analysis of the factors of the curriculum environment. To define the first big idea, the target audiences and the conditions of supply were identified. The target audiences are migrant children and youth between 10 and 17 years old with an interest in learning to program in Python. The conditions of the offer include the online and hybrid course modality, the dedication of 30 hours in total, and the daily load of 2 synchronous hours and 1 asynchronous hour. In this sense, the statement of the first big idea is programming is essential in the disciplines and is expected to develop as the first enduring understanding (EP1) society requires STEM professionals who solve problems using computational thinking (EP1a), and technological projects involve data, variables, expressions, operators, and functions (EP1b).

The second big idea (GI2) of Unit 2 defines what is to be learned and why, demonstrating what is to be learned and how to arrive at that knowledge. Therefore, the second big idea states that computer programs make decisions according to the execution conditions and the data supplied by the user. It is expected to develop as second enduring understandings (EP2) programs are executed according to truth values and defined conditions (EP2a). Data can be structured in dictionaries to store any value and identify them by keys (EP2b).

The third big idea (GI3) of Unit 3 determines what is expected to be learned with the teaching methodologies and educational resources required for the course. The statement of the third big idea is repeating instructions allows the development of more complex computational problems, and it is expected to develop as third enduring understandings (EP3) cycles allow to perform repetitive instructions to execute the program multiple times (EP3a), and data can be structured in one dimension with lists and dictionaries, or two dimensions with arrays (EP3b).

TABLE III
CONCEPTS PER UNIT

Unit	Big ideas	Enduring understandings
1	GI1: Programming is essential in STEM disciplines.	EP1a: Society requires STEM professionals who solve problems using computational thinking. EP1b: STEM projects involve data, variables, expressions, operators, and functions.

2	GI2: Computer programs make decisions based on execution conditions and user-supplied	EP2a: Programs are executed according to defined truth values and conditions. EP2b: Data can be structured in dictionaries to store any value and identify them by keys.
3	GI3: Repeating instructions allows the development of more complex computational problems.	EP3a: Cycles allow repetitive instructions to execute the program multiple times. EP3b: Data can be structured in one dimension (lists and dictionaries) or two dimensions (arrays).

Once the three big ideas were described, learning objectives (see Table IV) and outcomes (see Table V) were defined for each one, which are verbs that demonstrate the observable learning outcomes in each unit.

TABLE IV
LEARNING OBJECTIVES

Unit 1	Identify a problem by determining inputs, outputs, and constraints.
Unit 2	Design the solution to the problem through an algorithm that solves it.
Unit 3	Assess the solution using data structures and specialized Python libraries.

TABLE V
LEARNING OUTCOMES

Ability to apply knowledge of mathematics, science, and engineering.	Understand how data structures work to know how to use them in the IT solution.
	Evaluate different algorithms using Python programming structures.

The teaching methodologies (see Table VI) explain the pedagogical strategies used in synchronous and asynchronous activities.

TABLE VI
TEACHING METHODOLOGIES

Methodology to Reach Knowledge	Independent and autonomous development of programming workshops.
Methodology to Strengthen Knowledge	Participation in the forum for each big idea where the application of the concepts to everyday problems is discussed.
Methodology to demonstrate what has been learned	Through the development of a supervised STEM project as an observable outcome, with two deliverables, an initial idea, and a final project.

Learning assessment (see Table VII) defines the types of summative and formative assessment of what is learned.

TABLE VII
LEARNING ASSESSMENT

Unit 1	Forums Workshops Initial STEM Project
Unit 2	Forums Workshops
Unit 3	Forums Workshops Final STEM Project

The timetable (see Table VIII) shows the distribution by units over the weeks of the course.

TABLE VIII
SCHEDULE

Unit	Session	Topic
Unit 1 Introducing programming from STEM	1	1.1 Introduction 1.2 Data types
		Workshop 1: Anaconda work environment
	2	1.3 Variables, expressions, and Operators 1.4 Predefined functions
		Workshop 2: Variables and operations
	3	1.4 New functions 1.5 Console-based interface
		Workshop 3: Functions Initial STEM project
Unit 2 Decision Making	4	2.1 Booleans 2.2 Relational and Logical Expressions
		Workshop 4: Booleans
	5	2.3 Conditionals 2.4 Operations on Strings
		Workshop 5: Conditionals
	6	2.5 Dictionaries
		Workshop 6: Dictionaries
Unit 3 Repeating instructions	7	3.1 While
		Workshop 7: While
	8	3.2 Strings 3.3 For 3.4 Lists
		Workshop 8: Lists
	9	3.5 Path patterns 3.6 Dictionary traversal 3.7 File handling
		Workshop 9: Archives
	10	3.8 Composite data structure
		Workshop 10: Composite Data Structure Final STEM project

C. STEM Approach

The online and hybrid course was designed with a STEM approach, which means an instructional, interdisciplinary, and didactic approach. The instructional approach involves scientific inquiry practices, technological and engineering design, and mathematical analysis [26]. The interdisciplinary approach seeks to eliminate the traditional teaching of STEM disciplines to integrate them with real and relevant experiences [27]. The didactic approach develops an authentic context that allows connecting STEM disciplines to enhance the learning experience [28].

The STEM approach seeks to contribute to the workforce of the four STEM disciplines [29]. It is an inclusive approach, which is not exclusive to privileged populations with STEM skills, such as critical thinking, problem-solving, research, creativity, communication, and collaboration [30].

This course design seeks to promote inclusive classrooms for Venezuelan migrants in Colombia, Peru, and Mexico, their main destination countries. These migrants need to be included in the educational system to transform these countries towards the solution of their real problems through innovation [30].

IV. Conclusions

A 30-hour online and hybrid course was designed with a focus on big ideas, aimed at children and young migrants between 10 and 17 years of age who are interested in learning to program in Python, where they learn different data structures such as lists, dictionaries, tuples, and matrices, as well as file management, to apply these data structures to everyday solutions through computer programs. The general and specific design is expected to be piloted in the target population in the two main destination countries of Venezuelan migrants, Colombia, México, and Peru.

The results of the future pilot will make it possible to redesign the concepts per unit, the learning objectives per unit, the teaching methodologies, and the evaluation of learning. This redesign will make it possible to evaluate the relevance of the course for the development of computational thinking and to facilitate the social insertion of migrant children and young people in the destination countries.

In future work, it is proposed to evaluate other learning modalities, whether face-to-face, distance, or virtual, mixing the dimensions of the hybrid learning environment to adjust the learning outcomes to the social and economic context of migrant children and youth.

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