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Instructional Usability and Learner-User eXperience Assessment in a Virtual Reality Educational Milieu: A Deductive Tech-Instructionality Model from EdTech

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Abstract— **Educational Technology (EdTech) lacks a foundational, formal, scientific, epistemic theory. Therefore, it lacks native constructs/variables and an epistemological object of study for scientifically deploying its work. This study determines the existence (ontology) of the theorized constructs *Instructional Usability (UsI)* and *Learner-User eXperience (LUX)* and defines their characterization (epistemology). Both constructs were modeled and instrumented. Furthermore, a Tech-Instructionality Model (TIM) was theorized and developed in this paper, both analytically and empirically. The model integrates UsI and LUX as two pairs of constructs linked with two EdTech epistemological objects of study, the instructional interface and the instructional interaction in two assessment modalities, testing mode (user-learner view) and inspection mode (expert/designer view). Two instruments were developed and validated in this study for testing mode, the Instructional Usability Scale (SUsI) and the Learner-User eXperience Questionnaire (QLUX). Both instruments were tested in a non-immersive virtual reality educational milieu during the academic lockdown of the Covid-19 pandemic. The results show that both SUsI and QLUX consistently measured UsI and LUX, thus, providing a valid assessment for tech-instructionality and a foundation for constructing a scientific theory of EdTech.**

Keywords— Learner-Interface Interaction, interface design and assessment in STEM, Tech-enhanced Learning & Tech-mediated education, EdTech Onto-epistemology, Educational Innovation & Remote EdTech Research in Covid times, Higher Education, human factors & cognitive ergonomics, snowball heuristic inquiry technique

I. INTRODUCTION

One of the greatest challenges of EdTech as a discipline is its lack of a formal scientific theory [1]. Among the onto-epistemological requirements for a scientific discipline, EdTech should have defined objects of study and, consequently, a set of constructs/variables established within a set of research programs.

Since EdTech must evaluate technologies in education in its native variables as a hybrid discipline that encompasses technology and education without overlapping either the epistemological objects and constructs/variables from technology and/or education, this study proposes, develops, and assesses the Instructional Usability (UsI) and User-Learner eXperience (LUX) concepts as two native EdTech constructs/variables.

Both concepts are proposed as an analogy to Usability (Us) and User eXperience (UX), two technological constructs/variables from Human-Computer Interaction (HCI) in the technological domain. The choice of these two technological constructs and their extrapolation to the EdTech field is based on their compatibility with the conceptualization of the EdTech epistemological objects proposed in [2]: the *instructional interface* (𝕚̈) and the *instructional interaction* (λ̈), considering EdTech as a subdiscipline of Human Factors, with the Educational Technologist (ET) as an Instructional Human Factors (IHF) expert, and a big concern for the confluence of Technology and Education as knowledge fields. This implies understanding 𝕚̈ as a particular case of the Graphical User Interface (GUI), the technological interface (𝕚), or just *interface* as in the tech domain, and λ̈ as the case for technological interaction (λ, notation from [3]).

Us and UX are two widely theorized tech concepts, developed and applied in design and assessment in all domains and intersections of STEM disciplines, such as Ergonomics, the design of pencils, aircraft, space shuttles, and intelligent agents with Artificial Intelligence, with a considerable engineering disciplinary emphasis on the GUI/𝕚 concept, its design, and assessment [4].

Then, if the Us and UX concepts are applied to assess the ease of using technology (*tech* Usability) and the user's experience of such technology (User *tech* eXperience) in tech/STEM, mainly for GUI/𝕚 design and assessment, the rationale of this work is that these two concepts can be extrapolated as homologous concepts in the learning domain as the ease of using *educational* technology (UsI) and the experience of using such technology *for learning* (LUX) to design and assess the graphical user *instructional* interface (GUI^2/𝕚̈) and its surroundings.

To conceptualize, structure, apply, and validate UsI and LUX as two native EdTech constructs/variables within the educational field, we developed a theoretical model called the Technology Instructionality Model (TIM), integrating both the user's vision and that of the expert/designer/evaluator within the Learner-Interface Interaction (LII), as a framework in the educational domain, and as the counterpart to HCI in the

The conceptual foundation of this research was developed within project 266632 "Binational Laboratory for Smart Management of Energy Sustainability and Technological Training" financed through the CONACYT-SENER Energy Sustainability Fund (S0019201401) in the subproject: Electronics Remote Lab's Interface Instructionality linked to Energy Sustainability MOOCs.

technological field, thus, providing an assessment model for two of the essential tech/STEM constructs in a learning context.

In this scenario, the meta-questions could be: With what or how should these constructs be conformed, and what should they contain to define, conceptualize, characterize, and assess the Us and UX of interfaces whose main objective is instruction in any of its forms? To find answers to these questions, we established our research objective to define and structure UsI and LUX and how they can be modeled/assessed, taking the Us and UX constructs' concepts as an inspiration and a developmental theoretical basis, together with the applicable instructional and educational principles and guidelines.

Section II presents UsI and LUX theoretical and operational conceptualization, the Tech-Instructionality Model, its analytical development, and the design of two assessment instruments (SUsI and QLUX) with fieldwork deployment and tech description within the general methodological approach. Section III presents a general review of the SUsI/QLUX's reliability assessments and the UsI/LUX degree assessments of a Virtual Reality SuperMarket (VRSM) as a remote tech-mediated educational milieu. Section IV concludes this study by discussing the importance of native EdTech constructs and their implications. Both assessment instruments are presented as appendices.

II. METHOD

A. *Constructs conceptualization and definition*

To approach the UsI and LUX constructs (non-existing in prior scientific literature) and answer the questions posed in Section I based on an onto-epistemological, theoretical characterization of Us and UX in the learning domain and their assessment as native EdTech concepts, we defined both, which apply to the EdTech field and are based on the concepts applied in tech/STEM.

UsI, adapted from DIN EN ISO 9241-11, is a measure (the degree) of how well a learner-user in a specific learning context can use an instructional interface to achieve a defined instructional goal effectively, efficiently, and satisfactorily. It is the cognitive, educational perception of an instructional interface used in an instructional interaction process, thus answering the *What* of the epistemological object of study.

Accordingly, LUX, adapted from DIN EN ISO 9241-210, is the set of personal emotions, beliefs, preferences, perceptions, physical and psychological responses, behaviors, accomplishments, and effects that the instructional interaction with an instructional interface has on its learner-user before, during, and after using it to learn. It is the emotional, educational perception of an instructional interface used in an instructional interaction process, thus answering the *How* of the epistemological object of study. It is caused by $\ddot{\text{⅄}}$ with $\ddot{\mathbb{i}}$, therefore, it is one of the consequences of UsI.

B. *The UsI and LUX constructs' modeling, the TIM*

To model and operationalize the UsI and LUX constructs, we first structured the basic shape and the features to be considered in the design of the theoretical model. We established that it should model and evaluate Us and UX in both domains, technological and educational [5], and both user and expert (designer/evaluator) views. This is to generate a comprehensive assessment model that encompasses all the phenomena and processes involved in instructional interactions in technologically mediated milieus. The general cube structure of the proposed Tech-Instructionality Model (TIM) with its constituent elements is portrayed in Fig. 1. Tech-Instructionality stands for the *instructional capacity of technology* applied in an educational milieu and conceptualized by [6] as the quality of collective strength and ability of EdTech features that effectively promote teaching and ensure learning by improving instruction to increase student achievement and success.

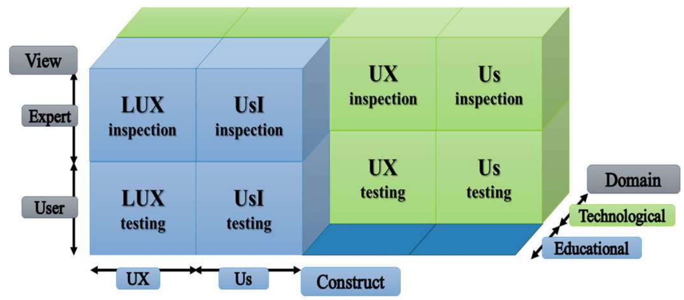

Fig. 1. Technology Instructionality Model's (TIM) general extended cubic structure.

C. *TIM's analytical development*

In analytical deduction, the TIM model is composed of two sections: 1) the technical assessment ($\mathbb{t}$) section (green blocks in Fig. 1) and 2) the technological instructionality assessment ($\dot{\mathbb{t}}$) section (blue blocks in Fig. 1). Considering the technical-technological instructionality ($\mathbb{T}$) as the meta-construct that represents the TIM's formal structure, its general analytical model is the following:

$$TIM(\mathbb{T}) = \mathbb{t} + \dot{\mathbb{t}} \tag{1}$$

In common practice, the Us and UX are assessed as the same instrument by exchanging and substituting them, or even by confusing them and evaluating one for another, mostly from the user's perspective, e.g., for mixing Us & Ux, there is the Usability Metric for User Experience (UMUX). Thus, the model for the technical assessment $\mathbb{t}$ is:

$$\mathbb{t} = User[Us/UX(\mathbb{i},\text{⅄})] + Expert[Us/UX\ (\mathbb{i},\text{⅄})] \tag{2}$$

The operationalization of $\mathbb{t}$ is already widely developed in the technological field. There are several instruments for this purpose, e.g., for the Us inspection (objective assessment/expert side), there is Nielsen heuristics, and for testing (subjective assessment/user side), the System Usability Scale (SUS). For the UX inspection, Empathy Maps/User-Persona, and for testing, the National Aeronautics and Space Administration Task Load indeX (NASA-TLX).

Thus, the model for $\dot{\mathbb{t}}$ is:

$$\dot{\mathbb{t}} = User[UsI(\ddot{\mathbb{i}}) + LUX(\ddot{\mathbb{i}}) + LUX(\ddot{\text{⅄}}) + UsI(\ddot{\text{⅄}})] + \ldots$$
$$+ Expert[UsI(\ddot{\mathbb{i}}) + LUX(\ddot{\mathbb{i}}) + LUX(\ddot{\text{⅄}}) + UsI(\ddot{\text{⅄}})] \tag{3}$$

where $UsI(\ddot{\mathbb{i}})$ and $LUX(\ddot{\mathbb{i}})$, are the assessments of the cognitive and emotional user's perception of $\ddot{\mathbb{i}}$ as an *epistemological object*, and $UsI(\ddot{\lambda})$ and $LUX(\ddot{\lambda})$ are the ones corresponding to $\ddot{\lambda}$ as an *epistemological action*.

This study develops and validates two instruments in testing mode (user's view, blue lower blocks, Fig. 1). To model LUX and UsI from the perception of the learner-user, two aspects are considered; first, the emotional perception of the action $\ddot{\lambda}$ minimizes its cognitive perception, and second, the cognitive perception of the object $\ddot{\mathbb{i}}$ minimizes its emotional perception; therefore:

$$LUX(\ddot{\lambda}) \rightarrow Min[UsI(\ddot{\lambda})] \therefore UsI(\ddot{\lambda}) \rightarrow 0$$

$$UsI(\ddot{\mathbb{i}}) \rightarrow Min[LUX(\ddot{\mathbb{i}})] \therefore LUX(\ddot{\mathbb{i}}) \rightarrow 0$$

By applying these considerations in (3), the theoretical model for the operationalization of UsI and LUX in testing mode (user's view) is:

$$\dot{\mathbb{t}}_{user} = UsI(\ddot{\mathbb{i}}) + LUX(\ddot{\lambda}) \tag{4}$$

This model corresponds to the two assessment instruments displayed in appendices 1 and 2.

Additionally, the evaluation of UsI and LUX in inspection mode (expert's view, blue upper blocks, Fig. 1) was developed as four elements in four scales of an objective assessment instrument. However, their validation processes are still under development at the IFE[1] Living Lab & Data Hub through multiple educational innovation research projects, which are yet to be concluded and will be presented in a future study.

D. Constructs operationalization and instruments design

In the same way that the extrapolation of constructs was conceptualized and carried out, the possibility of adapting and/or extrapolating the design and assessment instruments from the technological domain to the educational domain was analyzed [7],[8],[9], so that the foundations for the design and assessment of $\ddot{\mathbb{i}}$ could be laid. This was impossible because there is an essential difference between the technological and EdTech design. Although the GUI focuses on solving mediation problems between technology and humans, its design is essentially based on technological factors [10], whereas the design of $\ddot{\mathbb{i}}$, like EdTech itself, is essentially based on human factors, which are also specific to the IHF discipline from cognitive ergonomics ($\mathbf{e}$). Therefore, adapting theories and assessment instruments from the technological domain does not generate theories or instruments with variables within or applicable to the EdTech domain.

This difference poses the fundamental break point between HCI and LII, but it also indicates a direction that can be followed to develop the theories and instruments that comprise the TIM. Thus, the deductive content analysis method [11] from social sciences was applied with a heuristic approach [7] from the technological domain to find models, theories, frameworks, and instruments that could guide the model's development. This type of deductive analysis, unlike the classic method of qualitative content analysis, which is an eminently deductive method, *a priori* defines the categories that will be searched in the textual content being analyzed.

The deductive analysis supports a semantic analysis that allows finding terms/words that are not literally identical or from the same root as the original term, broadening the search and the possibility of obtaining results focused on their meaning. The main obstacle to proceeding this way is that it is entirely manual, which implies spending much time on revisions. Due to the process's highly heuristic and stochastic nature, it is currently impossible to automate it algorithmically. However, it is possible that Machine Learning (ML) techniques such as Natural Language Processing (NLP) could soon be applied to achieve a degree of automation.

Starting with the results obtained from literal term search indexers related to the *graphical user interface design/GUI Design*, with an exclusion criterion of unique appearance in the title, a first iteration of the snowball heuristic inquiry process is applied. Throughout this process, the titles, abstracts, and references of the resulting indexed articles are reviewed and semantically compared with the two *a priori*-defined terms (UsI/LUX). The snowball model is followed towards the articles that better match the researcher's criteria and proposed definitions or indicate a clue that can lead to the desired result. Once the articles to be reviewed have been chosen, a second iteration is carried out, and so on, until satisfactory results are obtained.

After performing searches in Scopus, WoS, and Google up to the sixth and seventh iterations, we determined that the methods, theories, and instruments that were close to the re/conceptualization serving as a foundation for developing the theory, instrumentation, and contextual constructs, were, for UsI, Mayer's multimedia learning theory, and the principles of multimedia e-learning design [12],[13], a set of scientifically proven guidelines for designing, developing, and evaluating digital multimedia learning displays (screens) and actions. For LUX, they were Hart's Task Load analysis theory within Human Factors theory with her NASA-Task Load Index [14],[15], an instrument evaluating cognitive/mental workload HF while performing a task in the aerospace research domain.

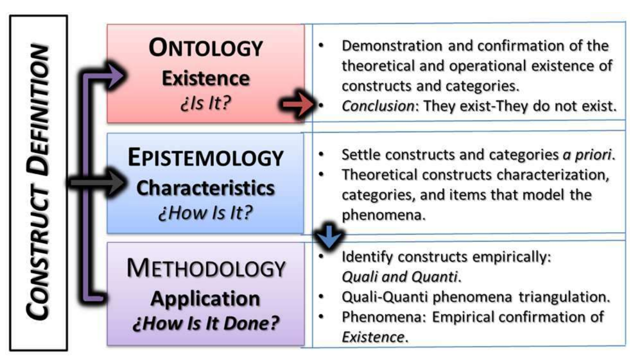

Fig. 2. Onto-epistemological and methodological questions, process, and steps for construct definition, inquiry, and validation. Adapted from [1]

The construct validation process of the instruments had an onto-epistemological approach [16],[17] since they are constructs that did not previously exist in the literature,

[1] Institute for the Future of Education, Tecnologico de Monterrey, Mexico.

implying the need to determine their existence (ontology) and characterization (epistemology). Fig. 2 shows the onto-epistemological validation process. Each instrument item asks a question about an essential construct characteristic for the study, and each instrument has as many questions as essential characteristics are needed.

Both assessment instruments were adapted to comply with the theorized characterization fully. The resulting instruments are:

1) The Instructional Usability Scale (SUsI, 14-Lk_5), a subjective scale for learner/student usage with 14 items in 5 steps' Likert metric (Appendix 1), assessing dimensions/IHF of multimedia, contiguity, coherence, personalization, pre-training, modality, redundancy, navigation, practice, collaborative learning, personification, signaling, affordance, and metacognition.

2) The Learner-User eXperience Questionnaire (LUXQ, 10-Lk_5), a subjective questionnaire for learner/student usage with 10 items in 5 steps' Likert metric (APPENDIX 2), assessing dimensions/IHF of effort, achievement, hedonics multimedia, epistemic emotions, achievement emotions, basic emotions, and learner experience.

To operationalize this resulting model and take it to the empirical evaluation stage, we integrated the assessment instruments for the two constructs in the form of the developed instruments [18], the SUsI based on Mayer's multimedia principles for UsI, and the LUXQ based on Hart's task load human factors for LUX, therefore:

$$UsI(\ddot{\mathbb{i}})_{user} \Rightarrow Mayer(\ddot{\mathbb{i}}) = M(\ddot{\mathbb{i}}) \quad (5)$$

$$LUX(\ddot{\lambda})_{user} \Rightarrow Hart(\ddot{\lambda}) = H(\ddot{\lambda}) \quad (6)$$

Thus, the analytical model for evaluation in testing mode is operationalized in this study by substituting (5) and (6) in (4):

$$\dot{\mathbb{t}}_{user} = M(\ddot{\mathbb{i}}) + H(\ddot{\lambda}) \quad (7)$$

E. Constructs and instruments validation: remote field study during a pandemic academic lockdown

A field remote operationalization study was carried out in two stages over 5.5 months amidst an academic lockdown during the Covid-19 pandemic. After the constructs' conceptualization, structuring, and theoretical process modeling, their empirical validation processes were developed in subsequent stages with two different technologies: (1) a remote online virtual reality (VR) educational milieu and (2) a remote online 360º video with augmented reality (AR) educational milieu, with the same students and under the same conditions. This paper presents the deployment of stage 1 (VR educational milieu), whereas the results from stage 2 (AR educational milieu) and a theoretical-practical comparison of both technologies remain to be presented as future work.

To begin with stage 1, we shared a link to the remote online non-immersive virtual reality educational milieu named Virtual Reality SuperMarket (VRSM, Fig. 3) with the principal of a higher education institution located in a semi-urban region in the central zone of Mexico having approximately 50 thousand inhabitants. The region only has basic services and Internet access in a few areas. The principal distributed the link among teachers, who, in turn, shared it with their groups of students.

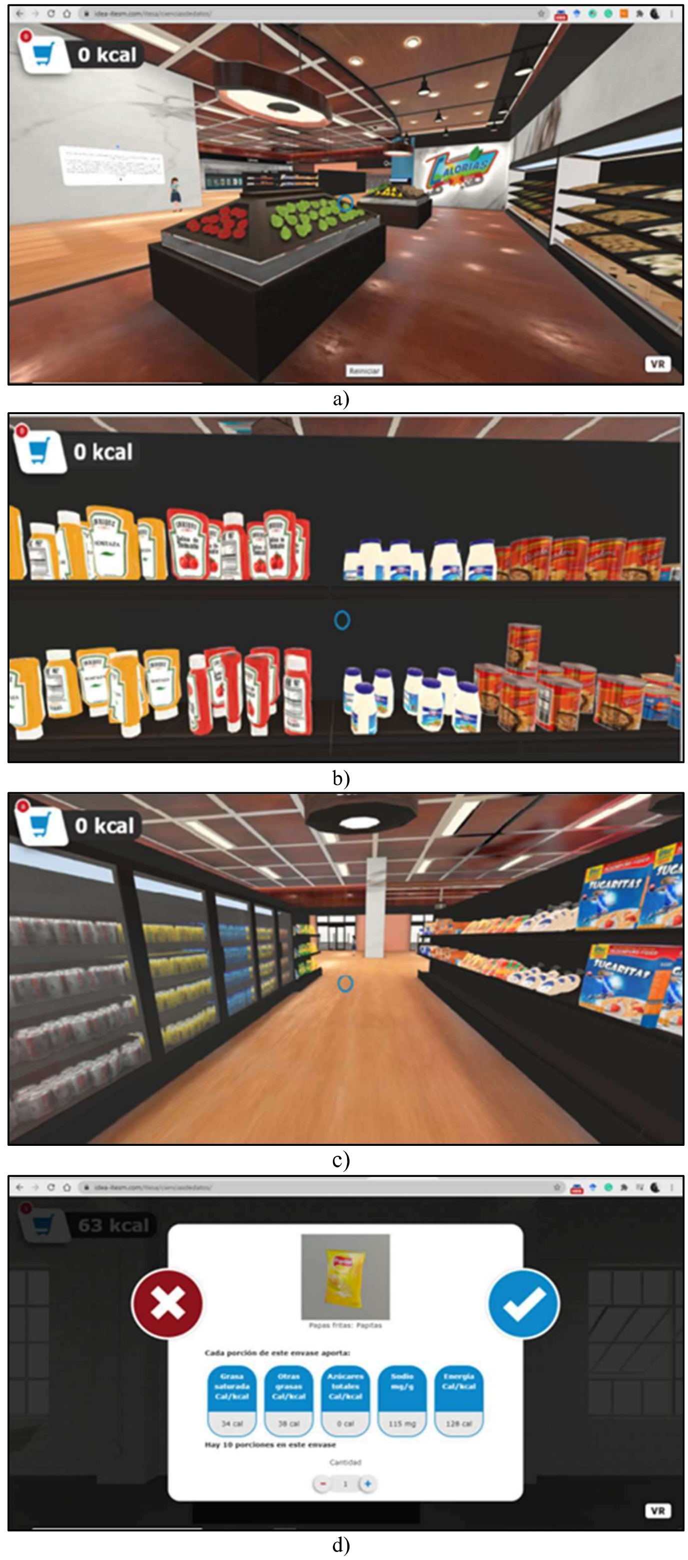

Fig. 3. VRSM screenshots: a) shelves with fruits and vegetables, b) products offered on conventional shelves, c) aisles with shelves and refrigerators, and d) nutritional information of the product available to the user, focusing on the number of calories in each product.

For this stage, a total capacity of 1000 university students from seven engineering and three additional bachelor's degree programs were considered. The groups were able to experiment with VRSM for three weeks, where they could interact with the environment, buy things, quantify the calories they could consume daily or weekly, and learn to manage their caloric intake in times of a pandemic, where the level of physical activity can decrease significantly (Fig. 3d).

After each group concluded with the experiments, a link to the assessment instruments of SUsI and QLUX was provided. Data collection and gathering were carried out remotely for the 1,100 research participants, including organizers, administrators, teachers, students, and researchers, who used cell phones and/or personal computers as access points. Then, the reliability of both instruments, SUsI and QLUX, was statistically evaluated, and the UsI and LUX degrees of the VRSM environment were evaluated.

III. Results

The results obtained from the reliability validation of SUsI and QLUX and the assessment of the degree of UsI and LUX in stage 1 (VR educational milieu) are summarized in Table I. The result of quantifying $\dot{t}$ for the VRSM environment, expressed in analytical terms and substituted in (7) is:

$$\dot{t}_{user/VRSM} = 0.58\ddot{\imath}_{M} + 0.61\dot{\lambda}_{H}$$

This means that the user's perception of the instructional capability of the VRSM environment is 58% instructional Mayer interface and 61% instructional Hart interface. The details for each outcome portrayed in Table I are detailed in the following subsections.

TABLE I. Results of instruments' reliability validation (SUsI & QLUX) and constructs assessment (UsI & LUX by user)

Tech applied	Instruments Reliability Cronbach's Alpha (α_c)		Degree (Grade) of	
	SUsI	*QLUX*	*UsI*	*LUX*
VRSM	0.9510[a]	0.8045[b]	58%[a]	61%[b]

[a]m=181. [b]m=597.

A. SUsI Reliability Assessment

A total of n=193 responses were obtained from the application of SUsI, from which m=181 valid responses were processed to determine the value of Cronbach's alpha (α_c) for the internal validity of the instrument (reliability). This resulted in an α_c =0.9510, which can be interpreted as an *excellent* value since it is within the range of 0.9 to 1.0 according to the ranking in [19]. Such value can also be interpreted as the instrument consistently measuring UsI.

Table II shows the reliability analysis results for the UsI instrument applied to the VRSM environment. If items M4 or M5 are eliminated, the reliability value increases by approximately half a percentage point, which indicates that they are most likely items that belong to the same factor and that their level of correlation is high enough for them to be measuring the same indicator in the same way. Therefore, both questions were merged into one that evaluates these two indicators together.

TABLE II. Results of instrument's reliability validation and constructs assessment for SUsI in the VRSM

SUsI α_c	SUsI's reliability per item removed (α_c)				
Item	***M4***	***M5***	***None***	***M13***	***M1***
α_c	0.9566	0.9549	**0.9510**	0.9476	0.9470
Item	***M9***	***M2***	***M6***	***M10***	***M7***
α_c	0.9465	0.9461	0.9460	0.9460	0.9458
Item	***M12***	***M14***	***M3***	***M8***	***M11***
α_c	0.9457	0.9456	0.9455	0.9455	0.9452

B. UsI Degree of VRSM

To assess the degree or percentage of instructional usability of the analyzed interface UsI_{user} ($\ddot{\imath}$), also interpreted as the degree or percentage of the instructional Mayer interface $M(\ddot{\imath})$ [12], the data is processed using the following formula:

$$M(\ddot{\imath}) = UsI_{user}(\ddot{\imath}) = \frac{1}{m}\sum_{j=1}^{j=m}\left(\frac{100\%}{r*L}\sum_{n=1}^{n=r}R_n\right)_m \quad (8)$$

where r=14 is the number of items in the instrument, L=4 is the maximum value of the applied Likert scale (0-4 step values), and m=181 is the number of students with valid responses. Therefore (8) becomes:

$$M(\ddot{\imath}) = UsI_{user}(\ddot{\imath}) = \frac{1}{181}\sum_{j=1}^{j=181}\left(\frac{100\%}{14*4}\sum_{n=1}^{n=14}R_n\right)_m \quad (9)$$

The calculations in (9) result in a value of $M(\ddot{\imath})$= 58.23% of instructional usability of the analyzed interface. Within the general scale of values of $M(\ddot{\imath})$ from the percentage ranges in Table III, this value denotes an *irrelevant* value with an *unacceptable* instructional Mayer interface degree. It means that the degree of instructionality of the interface is so low that it is an unacceptable interface for application in instructional or educational settings.

TABLE III. Instructionality Degree Ranking and $\ddot{\imath}$ & $\dot{\lambda}$ interpretation

Instructionality Degree Ranking and $\ddot{\imath}$ & $\dot{\lambda}$ interpretation		
$M(\ddot{\imath})/H(\dot{\lambda})$ Degree	**Degree interpretation**	**Instructional $\ddot{\imath}/\dot{\lambda}$ is:**
0%≤ $M(\ddot{\imath})/H(\dot{\lambda})$<60%	Irrelevant	Unacceptable
60%≤ $M(\ddot{\imath})/H(\dot{\lambda})$<70%	Low	Minimum
70%≤ $M(\ddot{\imath})/H(\dot{\lambda})$<80%	Moderate	Acceptable
80%≤ $M(\ddot{\imath})/H(\dot{\lambda})$<90%	High	Good
90%≤ $M(\ddot{\imath})/H(\dot{\lambda})$≤100%	Optimal	Ideal

C. QLUX Reliability Assessment

A total of n=640 responses were obtained from the application of QLUX, from which m=597 valid responses were processed to determine the value of Cronbach's alpha (α_c) for the internal validity of the instrument (reliability). This resulted in an α_c =0.8045, which can be interpreted as a *good* value since it is within the range of 0.8 and 0.899 according to the ranking in [19]. Such value can also be interpreted as the instrument consistently measuring LUX.

TABLE IV. RESULTS OF INSTRUMENT'S RELIABILITY VALIDATION AND CONSTRUCTS ASSESSMENT FOR QLUX IN THE VRSM

QLUX α_c	**LUXQ' Reliability per item removed (α_c)**					
Item	***H8***	***H9***	***None***	***H3***	***H4***	***H1***
α_c	*0.8245*	*0.8156*	***0.8045***	*0.7915*	*0.7837*	*0.7828*
Item	***H2***	***H6***	***H10***	***H7***	***H5***	-
α_c	*0.7803*	*0.7739*	*0.7735*	*0.7714*	*0.7698*	-

Table IV shows the reliability analysis results for the LUX instrument applied to the VRSM environment. If items H8 or H9 are eliminated, the reliability value increases by one and two percentage points, which indicates that they are probably items that belong to the same factor and that their level of correlation is high enough for them to be measuring the same indicator in the same way. Therefore, both questions were merged into one that evaluates these two indicators together.

D. LUX Degree of VRSM

To assess the degree or percentage of user-learner experience of the analyzed interface $LUX_{user}(\ddot{\lambda})$, also interpreted as the degree or percentage of the instructional Hart interface $M(\ddot{\text{ı}})$ [14],[15], the data is processed using the formula in (8) with r=10 as the number of items in the instrument, L=6 as the maximum value of the applied Likert scale (0-6 step values), and m=597 as the number of students with valid responses. Therefore (8) becomes:

$$H(\ddot{\lambda}) = LUX_{user}(\ddot{\lambda}) = \frac{1}{597}\sum_{j=1}^{j=597}\left(\frac{100\%}{10*6}\sum_{n=1}^{n=10} R_n\right)_m \quad (10)$$

The calculations in (10) result in a value of $H(\ddot{\lambda})$=61.02% of the user-learner experience of the analyzed interface. Within the general scale of values of $H(\ddot{\lambda})$ from the percentage ranges in Table III, this denotes a *low* value with a *minimum* instructional Hart interface degree. It means that the degree of user-learner experience of the interface is low and has the minimum interface characteristics for application in instructional or educational settings.

IV. DISCUSSION, CONCLUSIONS, AND FUTURE WORK

A. Discussion

This study proposes and validates a model to assess the degree of technology's instructional capacity for a tech-mediated virtual reality educational milieu concerning the ease of use for student learning (UsI) and their experience of its use (LUX).

The results show that the evaluated constructs, native to EdTech and previously non-existent in its practice, were not considered in the edtech design, which to some extent, justifies the minimal results of Tech-Instructionality in the evaluation carried out on the VRSM environment. The non-existence of these constructs in EdTech practice indicates a lack of knowledge of the effects and factors of using and applying these technologies in the educational domain.

The proposed model structures a first approach with formal nuances to lay the foundations for constructing a scientific theory of EdTech. The onto-epistemological proposal of constructs/variables, which are native to the discipline, opens the door to addressing this effort, mainly because the construction of instruments with items that epistemologically characterize a construct demonstrates the existence (ontology) of that construct and confirms a phenomenological methodology that can be followed for its evaluation and formal knowledge.

One of the opportunity areas to improve the VRSM design is to study the items of both instruments and analyze the IHFs that improve UsI and LUX for this educational environment, as well as to consider a redesign that improves its Tech-Instructionality. In addition to being validated and offered to EdTech researchers and practitioners shortly, the Tech-Instructionality Model for assessment in inspection mode (the expert side) would prove a robust objective model for evaluating and validating the design of educational technologies.

B. Conclusions

EdTech is essentially IHF. This study theorizes that UsI and LUX are valid onto-epistemological constructs shaped by valid IHF and have the formal characteristics to be part of the body of EdTech's scientific knowledge. The evaluated model directly fuses the technological and instructional elements and the new EdTech elements into a body of knowledge that generates a base to support EdTech as a scientific discipline. The model is methodologically valid to assess the EdTech instructionality of tech-mediated educational milieus.

The dimensions of the instruments structured as IHF adequately model the proposed constructs. In addition to answering the questions of what and how UsI and LUX should be constituted, they formally inform ETs of the elements, variables, and constructs essential in their work as theorists and practitioners of the discipline.

This study generates formal indications to consider that virtual reality environments attended remotely are not optimal for students in technologically and/or economically disadvantaged environments, conditions, or contexts because they need more technological resources for successful edtech implementation.

Finally, adopting a Tech-Instructionality Model, characterizing key IHF and "the interaction between them, would be useful for reform efforts to resolve the relationship between school development efforts and classroom teaching." [6]

C. Future Work

Future work will focus on two key aspects; the first will be aimed at broadening and extending the dimensions and variables that the model evaluates, adding other types of assessment instruments. The second will be directed toward validating the instruments' use and application in multiple contexts and educational settings. For this purpose, a collaboration with the IFE[2] Living Lab & Data Hub was established to share such instruments with the researchers participating in their upcoming and future edtech-based research and development calls.

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Appendix 1

Instructional Usability Scale (SUsI)
(English language non-validated version)

M1. The explanations or instructions given in the form of written text or in the form of narrated audio to explain videos, graphics, or images were simple, revealing, and easy to follow and understand.

M2. The animations and videos illustrated procedures and abstract ideas with signs and markings to focus and facilitate attention to details that are difficult to understand.

M3. The proximity of explanatory texts with their respective graphics facilitated their consultation, avoiding covering or separating information.

M4. There were graphics, videos, music, or extra sounds, which were very distracting and did not help concentration.

M5. The animations, videos, narrations, and texts were unnecessarily long or irrelevant, so much so that the idea or topic they were dealing with was lost.

M6. The friendly tone and manner of the texts, videos, animations, and narrations directed at me made it easy to focus on the subject.

M7. Introducing important or complex concepts and terminology before going to the to-do procedures helped to troubleshoot application problems better.

M8. The audio words of videos, animations, explanations, and instructions help to concentrate more and better on the subject than the words in the text.

M9. The pause/continue and back/forward controls to go to previously visited topics or places and repeat audio, video, or text help to relate ideas and understand concepts.

M10. Always having a progress indicator that shows the real position and the progress achieved in the activities carried out helps to organize and concentrate more on those that are missing.

M11. The help was explicit and direct enough, clear and relevant, and available to focus and concentrate thinking and encourage ideas.

[2] Institute for the Future of Education, Tecnologico de Monterrey, Mexico.

M12. Communication tools within the interface, such as sharing, searching, posting, chats, forums, and repositories, encourage collaboration and exchange of ideas and learning between users.

M13. The elements of the interface (buttons, signs, texts, environment, music, light, movement, etc.) correctly suggest the actions that each one of them actually performs.

M14. Answering these questions made me reflect on things I had not realized before, which can improve my future learning.

Escala de Usabilidad Instruccional (UsIE) (Version validada en lenguaje espanol- Spanish language validated version)

M1. Las explicaciones o instrucciones dadas en forma de texto escrito o en forma de audio narrado para explicar videos, gráficos o imágenes eran sencillas, reveladoras y fáciles de seguir y entender.

M 2. Las animaciones y videos ilustraban procedimientos e ideas abstractas con señalizaciones y marcas para enfocar y facilitar la atención en detalles difíciles de entender.

M3. La proximidad de textos explicativos con sus respectivos gráficos facilitaba su consulta, evitando cubrir o separar información.

M4. Había gráficos, videos, música o sonidos extra, que generaban mucha distracción y no ayudaban a la concentración.

M5. Las animaciones, videos, narraciones y textos eran innecesariamente largos o irrelevantes, tanto que se perdía la idea o tema que trataban.

M6. El tono cordial y la forma amable de los textos, videos, animaciones y narraciones dirigidas a mí facilitaban concentrarse en el tema.

M7. La introducción de conceptos y terminología importante o compleja antes de ir a los procedimientos a realizar ayudó a solucionar mejor los problemas de aplicación.

M8. Las palabras en audio de videos, animaciones, explicaciones e instrucciones ayudan a concentrarse más y mejor en el tema, que las palabras en texto.

M9. Los controles de pausar/continuar y regresar/avanzar para ir a temas o lugares visitados antes y repetir audios, videos o textos, ayudan a relacionar ideas y entender conceptos.

M10. Tener siempre un indicador de progreso que muestre la posición real y el avance logrado en las actividades realizadas, ayuda a organizarse y concentrarse más en las que faltan.

M11. La ayuda fue lo suficientemente explícita y directa, clara y relevante y estaba disponible en el momento necesario para enfocar y concentrar el pensamiento y favorecer las ideas.

M12. Las herramientas de comunicación dentro de la interfaz como compartir, búsqueda, enviar, chats, foros y repositorios, fomentan la colaboración e intercambio de ideas y el aprendizaje entre usuarios.

M13.Los elementos de la interfaz (botones, señalización, textos, ambiente, música, luz, movimiento, etc.) sugieren corretamente las acciones que realmente realizan cada uno de ellos.

M14. Responder a estas preguntas me hizo reflexionar en cosas que no me había dado cuenta antes, y que pueden mejoran mi aprendizaje futuro.

Appendix 2

Learner-User eXperience Questionnaire (QLUX) (English language non-validated version)

H1. How appropriate was the learning pace applied in the interface?

H2. How much mental effort did you have to spend with the interface to reach the final level of learning you achieved?

H3. How much physical effort did you have to spend with the interface to reach the final level of learning you achieved?

H4. How well did you manage to finish the learning activities that you had to do in the interface?

H5. How much do you feel you managed to learn with everything you did in the interface?

H6. How much do you feel that the interface's graphics and multimedia sounds helped you learn?

H7. How satisfied were you with what you managed to learn with the interface?

H8. How frustrated were you with what you couldn't learn with the interface?

H9. How confused did you feel with what you couldn't understand in the interface?

H10. How pleasant was the flow of the learning experience with the interface?

Cuestionario de eXperiencia de Usuario-Aprendiz (CLUX) (Version validada en lenguaje espanol- Spanish language validated version)

H1. ¿Qué tan apropiado fue el ritmo de aprendizaje aplicado en la interfaz?

H2. ¿Qué tanto esfuerzo mental tuviste que dedicar con la interfaz para alcanzar el nivel de aprendizaje final que lograste?

H3. ¿Qué tanto esfuerzo físico tuviste que dedicar con la interfaz para alcanzar el nivel de aprendizaje final que lograste?

H4. ¿Qué tan bien lograste terminar las actividades de aprendizaje que tenías que realizar en la interfaz?

H5. ¿Qué tanto sientes que lograste aprender con todo lo que hiciste en la interfaz?

H6. ¿Qué tanto sientes que los gráficos y sonidos multimedia de la interfaz te ayudaron para aprender?

H7. ¿Qué tan satisfech@ te sentiste con lo que si lograste aprender con la interfaz?

H8. ¿Qué tan frustrad@ te sentiste con lo que no pudiste aprender con la interfaz?

H9. ¿Qué tan confundid@ te sentiste con lo que no lograste entender en la interfaz?

H10. ¿Qué tan agradable fue el flujo de la experiencia de aprendizaje con la interfaz?