A Ubiquitous Learning Model for Education and Training Processes Supported by TV Everywhere Platforms

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Abstract—Advances in technology and digital convergence, for example Netflix, enable users to view TV and video without time or place restrictions. These advances can be applied in education and training processes to enable ubiquitous learning (u-learning). However, a literature review (of the years 2002 to 2018) on u-learning models yielded scarce information about its implementation, specifically demonstrating a lack of application alternatives that could provide access to TV regardless of place and device. To contribute to this and other challenges in education, the objective of this study is to propose a reference model for u-learning implementation involving cloud-supported TV/video platforms. The model was validated in a university context by a group of experts and applied through a prototype in a real setting with students, and it showed favourable results and improvement in student performance.

Keywords—u-learning, multiscreen, model, TV everywhere, cloud computing

1 Introduction

U-learning is a broad approach that encompasses various means and enables learning experiences linked to each person's place, pace, and setting. In ISO/IEC [1], u-learning is defined as learning that is stimulated and supported through various means and is always readily accessible. U-learning is not limited to a single place, which allows the expansion of learning experiences [2]. Students can access learning resources in an easier and more convenient way [3]. As El Guabassi *et al.* [4] outline, the system is ubiquitous if it is able to adapt to its context (user, platform, environment, device, etc.). According to Moreno Lopez *et al.* [5], u-learning is an ecosystem that fosters or complements learning beyond the traditional classroom. Through a convergence of technologies, it facilitates access to the right services anywhere and at any time. These services, in the most transparent and simplest way possible, provide individuals with a sense of continuous learning and motivation immersed in everyday life to learn and connect with the setting in which they develop.

Through the use of technology, u-learning seeks to bring learning closer to the places learners reside, where networks of students, faculty, and experts interact both synchronously and asynchronously without relying on specific schedules and places [6]. According to [7], ubiquitous learning allows access to educational resources with full mobility and system adaptation to the students' computational context. In general, as Shapsough and Zualkernan [8] indicated in the literature, u-learning is defined as learning anything, anywhere, and at any time.

U-learning itself benefits from broad technology development, digital convergence, increased bandwidth, content delivery networks (CDNs), adaptive bitrate (ABR) technologies, cloud computing, and ubiquitous computing, among others. For example, Cisco [9] projects that by 2023 there will be 29.3 billion networked devices, of which machine to machine (M2M), smartphones, connected TVs, PCs, and tablets are highlighted. In this scenario, video is projected to become the most popular content, representing 82% of all IP traffic by 2022. Video learning is becoming an increasingly important part of contemporary education [10].

Against this backdrop, video content can be adapted to any Internet-connected screen (PC, smartphone, tablet, smart TV). A new generation of cloud-supported and software-defined TV is emerging—the notion of TV Everywhere (TVE), which refers to deployed video content that can be viewed everywhere on a variety of Internet-connected screens [11]. Initially, when cable operators began to use it to offer online television programming, TVE was technically known as multi-channel video programming distributors (MVPD) [12]. There are several terms related to TVE, such as software-defined TV, Cloud TV, TV streaming, Over-the-Top (OTT) TV, multi-screen TV, software-defined video processing, and TV as a Service (TVaaS). Based on the premise of ubiquity, ubiquitous TV is presented as television that is supported by a convergence of technologies and connectivity, which can be seen everywhere, at any time, and on any screen. These terms are covered under software-defined everything, which, according to Virmani [13], refers to a varied group of software-defined computing technologies within a general framework and design. In addition, cloud computing service models serve as a deployment reference: Software as a Service (SaaS), Platform as a Service (PaaS), and Infrastructure as a Service (IaaS), as well as essential features, namely, on-demand self-service, extensive network access, resource pooling, rapid elasticity, and measured service [14]. A highly-used term is video streaming, a technique that allows customers to start playing a video without having to download the entire file [15]. For example, Netflix is one of the world's leading streaming platforms [16], [17].

While u-learning models have been well defined in the literature, there is a particular lack of cloud-supported TV technologies, greater model detail, and consideration from a pedagogical approach (for instance, in instructional design theory), and universities rarely adopt them. The motivation behind this study is to project the applicability of TVE platforms that enable video adaptation and delivery to different types of screens, with a link to the u-learning approach. Therefore, this paper proposes a u-learning model backed by TVE platforms and provides the results of a systematic literature review as well as illustration and validation of a prototype.

2 Method

The adopted research paradigm was post-positivism, which is flexible and seeks objectivity. The research approach was quantitative [18], [19]. In general, the design-based research [20] methodology was applied, which seeks to improve educational practices through iterative analysis, design, development, and implementation.

The research design had two scenarios (Figure 1): one non-experimental model assessment with a group of educational technologies experts and a quasi-experimental model that explored prototype application in real courses. In both, the sample was targeted and the data analysis was descriptive and factorial. In the quasi-experimental model, a pre-test/post-test design was also implemented [21] to evaluate students' academic performance. There was a control group (traditional lecture) and an experimental group (u-learning and TVE). Afterwards, the experimental group evaluated a prototype called "Aprenutvi" by answering a survey.

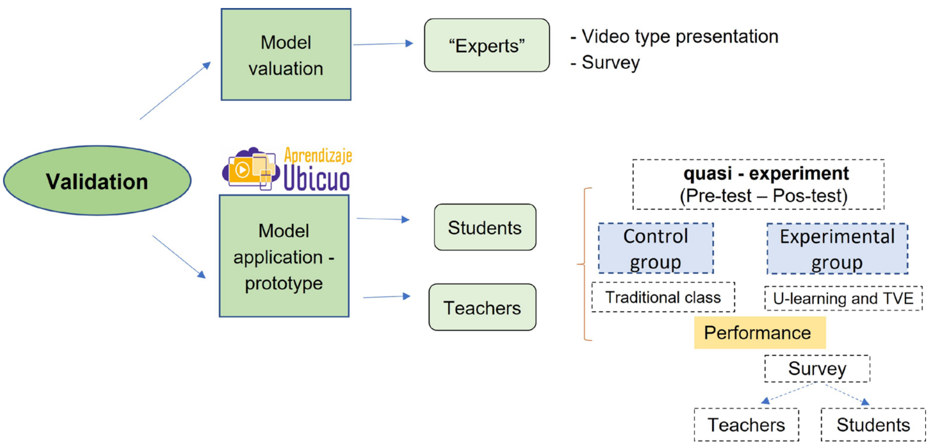

Fig. 1. Validation process summary

2.1 Sample

For the model evaluation, 19 experts from 17 universities fully completed a survey, out of approximately 65 individuals who responded to an e-mail request. These data were collected from May 2018 to May 2019. The implementation and evaluation of the Aprenutvi prototype was conducted during the second semester of 2018 and the first semester of 2019 in the Algorithms and Coding course (Faculty of Engineering, Politécnico Jaime Isaza Cadavid [Poli JIC]) with 44 students (22 in each control and experimental group), and in the History and Theory 2 course (School of Architecture, Universidad Nacional de Colombia [UNAL Medellín]) with 43 students (control group: 21, experimental group: 22).

2.2 Tools

For the model evaluation by the group of experts, a survey-type tool (in Google forms) was developed that consisted of a 15-item Likert scale containing five response alternatives (1 = Strongly Disagree to 5 = Strongly Agree). It was also based on some of the ISO/IEC 25010:2011 standard indicators for a product or system evaluation in the areas of quality in use and product quality [22]. Another indicator is the intention of use [23], as shown in Table 1.

Table 1. Reference indicators for evaluation provided by the group of experts

Indicator	Characteristic	Items
Usability in use	Satisfaction – usefulness	9
Product usability	Appropriateness recognizability Learnability Operability Accessibility	1 2 1 1
Intention of use		1

In the prototype assessment, an instrument was also created, consisting of a 23-item, Likert-type scale, as shown in Table 2. Another indicator is performance (pre-test and post-test); the UNAL and Poli JIC professors develop the tests, the presentation of the theme, and then do a video recording.

Table 2. Reference indicators for prototype evaluation

Indicator	Characteristic	Items
Usability in use	Effectiveness, efficiency, satisfaction (usefulness, trust, pleasure, comfort)	7
Context coverage	Flexibility, context completeness	2
Functional suitability	Functional correctness	1
Product usability	Appropriateness recognizability, learnability, operability, user error protection, user interface aesthetics, accessibility	9
Portability	Adaptability	1
Reliability	Availability	1
Intention of use		2

2.3 Procedure

For the model evaluation by the group of experts, a request was sent to them via an e-mail containing the online survey. During the prototype evaluation, the professors of both courses first conducted the pre-test. Then, the traditional lecture was presented to the control group and the implementation of cloud TV-based u-learning was carried out with the experimental group. Subsequently, the professors conducted the post-test for both groups. Finally, only the experimental group took the online survey in order to evaluate the experience.

3 Results

3.1 Literature review

The systematic literature review process was based on the work of Kitchenham and Charters [24], which has three phases: planning, execution, and review reporting. During this process, 4,868 articles were obtained (from the years 2002 to 2018), 4,767 of which were discarded since the titles did not make any reference to a u-learning model. During this stage, 101 items were obtained. Only articles from journals or books were kept, resulting in 53 items being discarded. Of the remaining 48 articles, duplicate articles were discarded, and upon conducting a more complete literature review, those that did not involve the implementation of a u-learning model were also discarded. From this review, 17 articles were left for further analysis, as outlined in Figure 2.

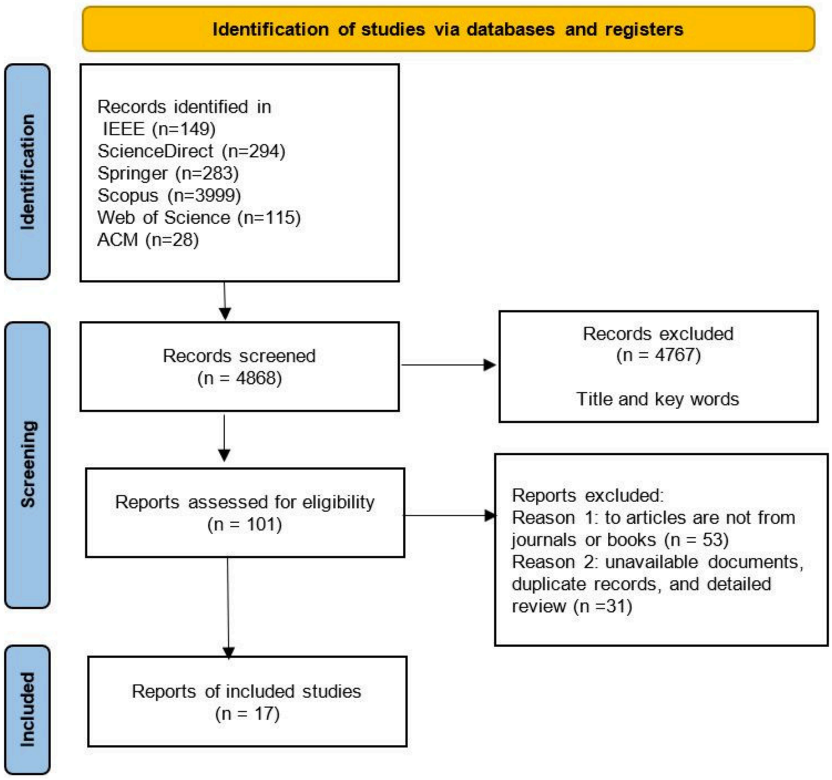

Fig. 2. Summary of the literature selection process

Following a review of relevant literature on u-learning models, several details were noted. With the exception of Zhao and Okamoto [25], very few studies mention the use of multiple devices. To some extent, several models present good information [25], [26], [27], [28], [29], [30], [31], [32] and [33]. Certain studies reflected the possibility of using other information and communication technology (ICT) resources [34], [35], [36], [25], [27], [37]. As for the degree of coverage or improvement, some authors project it to be broader, such as [37], [38], on campus [27], [28], [29], [39], in the classroom [40] and in simulations [31], [26], [35]. Regarding context awareness, most implement this feature through, for example, employing RFID sensors [39] and WSN sensors [29]. In terms of main infrastructure/technology, several authors use a server client, as in the case of Shih *et al.*[39] through the use of RFID, tablet, PC and wireless sensors [25], while other authors use PC and mobile sensors [35], XML, ASP.net, and mobile sensors [34], and mobile and WSN sensors [29]. Tortorella *et al.* [32] use a Raspberry Pi 2-based system, and Rabello *et al.*[31] use agents. With regard to real deployment tests, several studies have conducted them, such as Tortorella *et al.* [32], who applied them to driving training. With respect to application domain, some are specific, for example plant education [27], teacher training [28], mathematics [39], use of text messages [2], driving training [32], computer science, and smart cities [33]. Some are implemented on campus (school, classroom), others are generic, and still others generally have a university application [37], [38]. The following table shows the general findings of the analysis of selected articles, according to certain defined characteristics.

Table 3. General findings of the analysis of selected articles

Characteristic	**Finding**	
	Notes	***Percentage***
Degree of detail in model	From a more comprehensive perspective, more elements are necessary to guide its implementation.	12% Low 82% Average 6% Broad
Multi-screen deployment	Only one study suggests that the solution can be deployed across multiple devices.	6% Yes
Main use of video	None have it as a primary resource.	0%
Incorporates more ICT resources	Six studies generally have them, others regularly, and others minimally or not at all.	35% Yes 24% Regularly 18% Minimally 23% No
Degree of coverage	Only three have a broad approach; most of them have a mid-range approach since they focus on one campus, while others are simulated.	18% Broad 23% None 12% Limited 47% Mid-Range
Pedagogical orientation	Connected theory, constructivism, project-based learning, and collaborative learning approaches.	0% Instructional design theory
Context awareness	Over half of them consider it.	65% Yes 29% No
Main infrastructure/technologies	Client-server infrastructure, mainly use mobile, PC devices. Some have sensors and agents.	0% Cloud supported/screen diverse
Real deployment test	On average, they conduct real deployment tests. Some are limited in terms of coverage and devices.	41% Yes 53% No 6% Simulated
Application domain	Some are specific. On campus. Generic. Schools. Scarce in university settings.	(18%) Application in a university

The complete details of the analysis of the selected articles can be reviewed in the following link figshare.

3.2 U-learning model with TV everywhere platforms

The model is developed referencing the Analyze, Design, Develop, Implement, and Evaluate (ADDIE) instructional design approach because it is widely accepted and functional as well as easy to use [41], [42]. The model is defined as an ecosystem in which multiple items factor in and, to a certain degree, contribute to the u-learning solution. It has several levels, each of which has a group of factors and components, as shown in Figure 3.

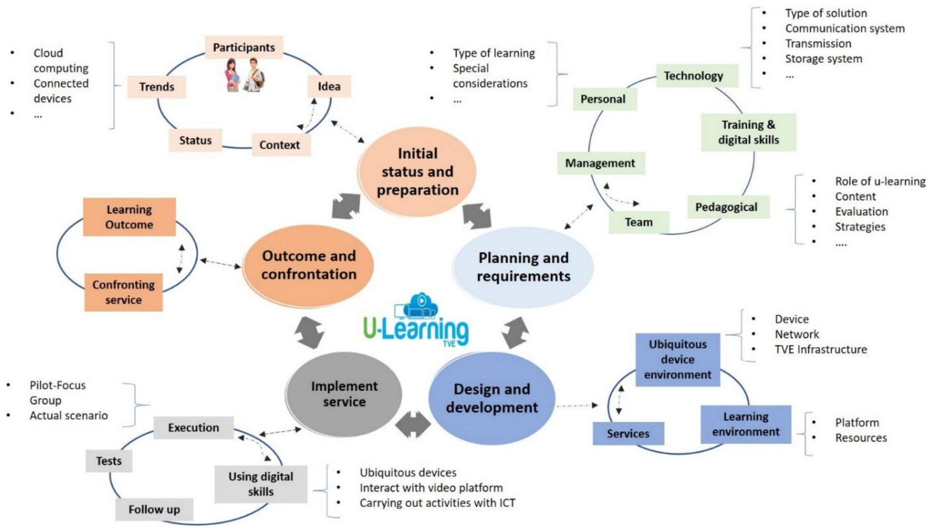

Fig. 3. U-learning model

The first phase, initial status and preparation, includes the idea of u-learning and multi-screen TV. It considers technology trends, application context (e.g., university), and participants, with students as the main actors. In the second phase, planning and technological requirements are defined (technologies that enable TVE, communication systems among participants, modes of interaction, storage, etc.). From a pedagogical standpoint, factors such as the role of u-learning (complementary, face-to-face, and virtual), content, activities, and strategies such as flipped classroom or gamification, among others, are projected. According to Collazos Ordóñez *et al.* [43], u-learning not only implies technological changes but also requires methodological and didactic changes to enhance learning, including establishing an interdisciplinary team (lecturer, multimedia developers, engineers, etc.), identifying personal needs and management-related factors, and defining training needs or areas for strengthening digital skills. In the third phase of design and development, the u-learning solution, content, and activities, among others, are outlined. The platform, resources, services, content, and others are configured or developed, and the video pre-production, production, and post-production are studied. The main components are the ubiquitous device environment (screens, Internet, TVE infrastructure), a learning platform, and services. The fourth phase of the u-learning service implementation aims to confirm the platform's functionality, execute it in real scenarios or focus groups, and track and make wide use of it. Finally, in the fifth phase, the learning outcome and service are evaluated, at which time the experience, impact, and teaching/learning process enhancement are reviewed.

Among the various forms of u-learning with TVE characteristics, the following are proposed: accessibility, immediacy, interactivity, functionality, context sensitivity, safety, scalability, flexibility, customizability, usability, learnability, interconnectivity, daily ubiquity, portability, measurable, manageable and multi-factored (plus other factors, e.g., multimodal or multi-screen). When some or all of these are connected, they foster a suitable u-learning ecosystem.

Figure 4 illustrates u-learning projections using cloud-based TV/video platforms and the use of various ICT resources complementing the solution.

Fig. 4. U-learning plan with TV streaming

3.3 Prototype

The u-learning and TVE prototype was defined considering the proposed model, called "Aprenutvi" (aprendizaje ubicuo basado en la nube y televisión/video [cloud-based ubiquitous learning with television/video]). Figure 5 shows an illustration of the prototype supported on the video platform Vimeo that is linked to the aprenutvi.co domain, through which the video portfolios for the courses are also linked.

Fig. 5. U-learning and TVE prototype illustration

3.4 Model validation and prototype implementation

The model was evaluated by a group of 19 experts: 11 men (57.9%) and 8 women (42.1%). In general, the perception about the u-learning and TVE model and concept is positive. Table 4 presents a summary of the most notable responses. For example, in the usability-in-use assessment, which measures user satisfaction, the fact that 63.2% strongly agree that TVE platforms are useful and benefit u-learning implementation is highlighted. The instrument in general has an internal consistency of 0.946, according to Cronbach's alpha [44].

Table 4. Overall results of the expert group evaluation

Indicator	Characteristic	Outstanding results
Usability in use	Satisfaction - use-fulness	63.2% (SA) and 31.6% (A), TVE utility for u-learning. 47.4% (A) and 36.8% (SA), model elements First level - 42.1% (SA) participants, 52.6% trends, 63.2% context Second level - 63.2% (SA) work team, 52.6% technological, 73.7% pedagogical Third level - 78% (SA) learning environment Fourth level - 68.4% (SA) service monitoring Fifth level - 57.9% (SA) service impact
Product usability	• Appropriateness recognizability • Learnability • Operability • Accessibility	52.6% (A) and 26.3% (SA) 36.8% (A) and 57.9% (SA) 63.2% (A) 73.7% (A)
Intention of use		31.6% (A) and 63.2% (SA) in employing TVE for educational use

(SA): Strongly Agree. (A): Agree

Five factors were obtained from the exploratory factor analysis and were validated via structural equations [45], as depicted in Figure 6. Factor (F1) has a high correlation with the idea component (u-learning and TVE). Factors 2, 3, and 4 are directly associated with the first-level components of the model related to participating actors (such as students), process expectation, and the usefulness of the model and application in any institution, respectively.

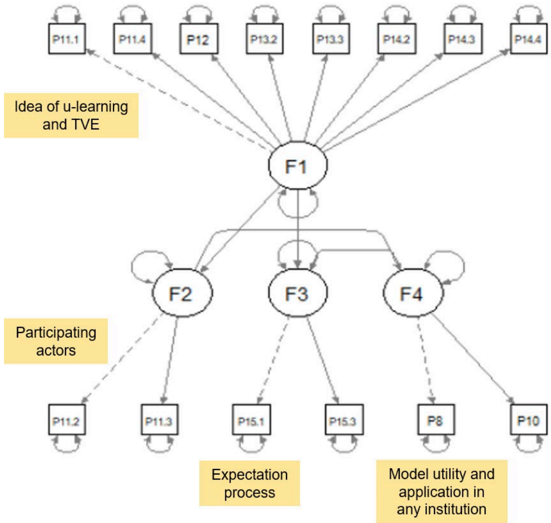

Fig. 6. Result of expert group evaluation of structural equations

Another scenario validates the application of the model using the prototype. As for the academic performance indicator, it is shown that when implementing u-learning and TVE, there is an overall improvement in results (see Table 5).

Table 5. Results of student performance tests

Subject	Group	Number	Pre-test average	Post-test average
History and Theory 2 (UNAL)	Experimental	21	4.0	4.5
	Control	22	4.5	4.5
Algorithms and Coding (Poli JIC)	Experimental	22	2.3	3.5
	Control	22	2.1	2.8

Table 6 shows the results of the statistical analysis of the grades obtained in the experimental and control groups using the chi squared test. The data obtained from UNAL have statistically significant differences since the p-values for each of the groups were lower than the significance level, while the data obtained from the Poli JIC experimental group did not provide sufficient evidence to establish a statistically significant difference.

Table 6. Results of statistical analysis of student performance tests

University	Experimental Group	Control Group
UNAL	0.0006074	0.006482
Poli JIC	Statistically non-significant	0.05657

Twenty-two students from the Algorithms and Coding course (Poli JIC) and 24 students from the History and Theory 2 course (UNAL) participated in the survey. In general, a positive perception from the students who participated in the prototype was observed, as illustrated in Table 7, which provides response highlights. For instance, in the usability-in-use evaluation (the indicator of satisfaction-utility), a notable 68.2% of respondents from Poli JIC and 79.2% of UNAL strongly agreed that they would recommend that universities implement video platforms to support ubiquitous learning. Overall, the instrument's reliability was 0.928 and 0.933 for Poli JIC and UNAL, respectively.

Table 7. Overall results of the student evaluation

Indicator	Characteristic	Outstanding Results (%)			
		Poli JIC		***UNAL***	
		A	SA	A	SA
Usability in use	Effectiveness	50	36.4	50	36.5
	Efficiency	45.5	54.5	54.2	45.8
	Satisfaction (usefulness)	31.8	68.2	16.7	79.2
	Satisfaction (trust)	63.6	9.1	58.3	33.3
	Satisfaction (pleasure)	68.2	13.6	65.2	29.2
	Satisfaction (comfort)	68.2	9.1	65.2	29.2
Context coverage	Flexibility	36.4	50	37.5	54.2
	Context completeness	59.1	22.7	8.3	41.7
Functional suitability	Functional correctness	40.9	54.5	66.7	33.3
Product usability	Appropriateness recognizability	59.1	27.3	41.7	37.5
	Learnability	36.4	63.6	37.5	54.2
	Operability	50	50	25	66.7
	User error protection	36.4	4.5	25	8.3
	User interface aesthetics	68.2	9.1	37.5	25
	Accessibility	68.2	18.2	37.5	50
Portability	Adaptability	63.6	18.2	33.3	50
Reliability	Availability	54.5	31.8	41.7	45.8
Intention of use		22.7	72.7	50	50

Note: (SA): Strongly Agree. (A): Agree

Four factors were obtained from the exploratory factorial analysis and validated via structural equations (see Figure 7). For example, for Poli JIC students (Figure 7-a), of note are factor one (F1), which has a high correlation for usability in use (effectiveness), factor four (F4) satisfaction (trust), factor three (F3) product usability (learning capacity), and factor two (F2) reliability (availability).

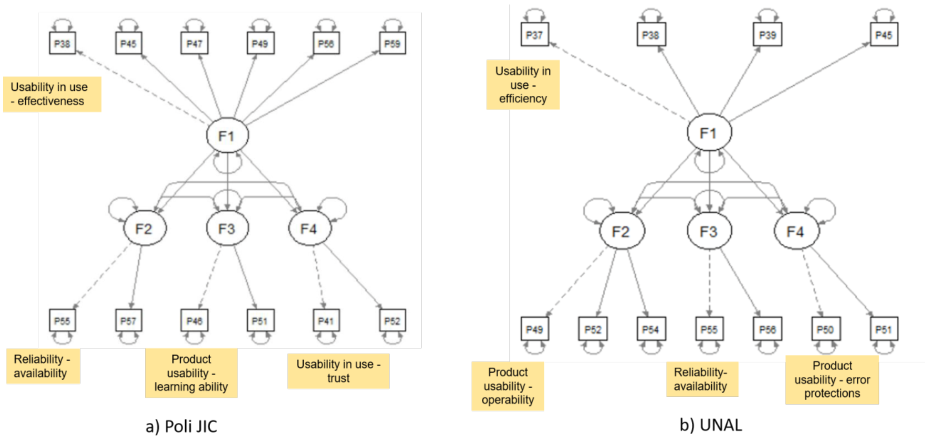

Fig. 7. Results of structural equations for Poli JIC and UNAL students

The three professors who participated in the implementation of the prototype also evaluated the subject and activity positively. For example, 66.7% strongly agree on the usefulness of TVE platforms and their benefit for u-learning, in addition to the usefulness of the model and implementation in any institution. They are all strongly in favour of the technological components and the need for digital skills training or strengthening.

The full data of the survey results can be accessed from the following repository figshare.

4 Conclusion

The study endeavoured to present a u-learning model with TVE platforms evaluated by a group of experts and to observe the impact of its application in a real-world scenario by means of a prototype. Overall, the results were satisfactory. On the one hand, the use of the u-learning application supported by streaming TV has favourable effects on students' performance. According to the evaluation, it can be concluded that there is a positive perception of the model as it relates to how it can contribute to the learning process.

The u-learning approach with TVE platforms assumes a scenario where Internet, technologies, and platforms that enable content can be shown on any screen. The applicability of u-learning is enhanced by a multi-screen TV. TVE platforms have a high potential for resource optimization because they are based on cloud computing, which allows for on-demand access to computing and infrastructure resources. When conducting experimental testing, the results demonstrated that the implementation was fast and the performance of the video platform was satisfactory. In terms of its applicability in an educational context, it can help solve issues related to flexibility and coverage, among others. Moreover, it makes it possible to employ other strategies such as flipped classroom or gamification.

The model's aim is to promote comprehensive consideration of the u-learning solution. Several stages were proposed in which factors and elements, to some degree, contributed to the implementation of u-learning. While it involved using cloud-based TV/video platforms, defining ICT implementation options or other resources remains open to individuals' discretion. From a comprehensive perspective, it involves not only having the technologies but also thinking about pedagogical issues, among others. As Holland and Judge [46] indicated, a successful combination of technology with innovative pedagogical practices is necessary.

There were elements that stood out when comparing the model and topic presented in this document with those of several authors: multi-screen visualization, detailed information for implementation, video as main content, and the use of convergent technology such as cloud computing, CDNs, and TVE. In addition, the model suggests working on acquiring digital skills that expand the possibility of learning, working, and sharing in the digital ecosystem, and it falls within the framework of instructional design theory known as ADDIE. It can be applied in colleges and other settings.

A big challenge in educational institutions is the shift in paradigm. According to Virtanen *et al.* [47], the teaching methods found in many universities continue to be conventional and strongly professor-based. As Liu *et al.* [30] indicate, u-learning facilitates a student-centred learning experience by allowing the student to define the time, place, and ICT resources. Gaining a better subject understanding is possible through video, and it is useful in complementing laboratory practices and improving training in equipment management. According to Strecker *et al.* [48], the learning experience is improved through abundant resources, including videos.

To a certain extent, TVE-based u-learning can contribute depending on the different learning styles or rhythms. Videos can be paused and re-watched to bolster understanding. Immersive experiences can be achieved via videos, and thus, as Lui and Slotta [49] state, allow for different perception, reflection, or integration opportunities of scientific understanding. Hung *et al.* [50] indicate that levels of reflection are improved when videos are used. In addition, students' communication skills can be improved [51]. Authors like Brame [52] claim that videos are a highly effective educational tool, integrating cognitive load, student engagement, and active learning. Li [53] emphasizes that playing the questions in the learning video can enable to students to review and consolidate their knowledge over time and improve learners' learning experience and learning effect to a certain extent.

As a future study, application and projection of the model is proposed in other scenarios in populations with diverse needs for systematization of the model, development of specific applications, adding technological elements, such as artificial intelligence (e.g., for smart information searches), or expanding context-sensitive applications. Moreover, pedagogical components (support, follow-up, and personalized and adaptive learning) track technological trends such as guidelines, and research and application of emerging technologies (immersive content, applying virtual reality [VR], mixed reality [MR], augmented reality [AR], or haptic technologies) or other technologies such as computer vision and speech recognition are proposed.

Competing interests

The authors declare that they have no competing interests.

Data availability statement

The dataset that supports the findings of this study are openly available in figshare at https://figshare.com/s/7720653edb0c70e33047.

Supplemental online material

The complete details of the analysis of the selected articles can be reviewed in the following link figshare.

5 Acknowledgment

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