Is t-Learning a mature Technology?
A systematic review of the literature


Abstract—This article presents a systematic review of the literature related to learning through digital interactive television, called t-learning. The goal was to answer the following question: Is t-learning a mature technology? For this purpose we performed a broad systematic review, analyzing the publications in the area through a research in the major scientific databases. After applying inclusion and exclusion criteria, 38 relevant articles were found in the area since 2004. At the end are presented an analysis and discussion about the state of the art in the area of distance education using digital television as a means of interaction between teacher and student.

Index Terms—Digital Television, Distance Learning, Electronic Learning, Interactive Systems

I. INTRODUCTION

T-LEARNING is a technology that, if mature, has a great potential to assist researchers in the areas of education, knowledge engineering, professionals in distance education (DE), and others. This research was motivated by the growing development of distance education, which shows that technology helps in teaching because it allows different forms of learning, and also by the growing attention given by governments in developing national plans for distance education [1]. In Brazil, especially, Interactive Digital Television (iDTV) has been a focus of the Brazilian government in order to support digital inclusion [45]. iDTV has the potential to assist digital inclusion because viewers are used to handling the remote control [1] [2] [3] and due to the fact that over 90% of the population have TV sets at home until 2009 [43].

Therefore, there is a need to check how mature are the researches in this area in order to identify the key challenges and opportunities related to t-learning, and what are the needs and gaps to implement this technology on the market.

This article aims to synthesize the state of the art of t-learning technologies and experiences in the context of iDTV. The goal was to try to find answers for the following question: Is t-learning a mature enough technology? From this question, we want to detect what is already possible and what is still missing for this relatively new technology. And further, find out relevant research themes for future works and help the development of distance education through iDTV. For this purpose we performed a systematic review of the literature, focusing on both, technologies and experience reports. The review evaluates and interprets all relevant researches from an issue or topic.

The systematic approach for the collection of all articles published since 2004 in major scientific databases was based on a list of criteria for inclusion and exclusion, focusing on the areas of Computer Science and Information Systems. The articles included were the ones presenting a case study, development, implementation or testing of an interactive application, a framework or a tool for t-learning. We discarded articles that only discuss the subject, without a practical application, as well as articles whose focus was e-learning for mobile, desktop and web platform, without addressing the television as the main subject.

II. MATERIAL AND METHODS

Following the recommendation process described in [5] and using some methods used in [44]. The steps described below were executed.

A. Planning the Review

This step consisted in identifying the need for review and creation of systematic rules, the research question and the inclusion and exclusion criteria, as mentioned earlier.

The research question of this systematic review makes the comparison of results harder, as exemplified in [5], where areas such as medicine become favorable to the systematic review because of the ease in comparing and testing

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methodologies. But, even so, this review has become necessary to study the reports contained in these articles, such as lessons learned, problems found, user testing and especially to determine if this technology is already being used in the market.

B. Extraction of data using pre-defined criteria

The string selected for the search consisted of a list of terms that express the concept of television + digital + education. To this end, synonyms, abbreviations and any other variation of the written word were selected. For TV and Digital were selected the following words “television, TV, digital, interactivity, interactive, DTV, ITV, iTV, TVD, TVDi”. The abbreviations TVD and TVDi were include as key-words because they are acronyms in Portuguese and Spanish, and may mistakenly appear in texts. For education, the following words were selected: “education*, learn*, e-learning and t-learning”. The search string resulted in:

(learn* OR education OR educational OR t-learning OR e-learning) AND ((television OR TV) AND (digital OR interactivity OR interactive) OR DTV OR iTV OR TVD OR TVDi OR ITV).

This search string was used to search titles, abstracts and key-words of the articles. Some databases have a character limit or different ways to specify an advanced search. Due to this reason, the appendix of this article contains all the strings used in the databases. The respective search strings were applied to the following scientific databases: IEEE Explore, ACM Digital Library, ISI Web of Science, ScienceDirect, Wiley and Springer.

Some databases, such as ACM Digital Library provide references to articles that are stored in other databases, such as Springer and IEEE Explore. In this case, the article was considered only if it was in the original database. In contrast, repeated researches published in different articles, or if the same study had more than one publication, those articles were included in the review.

The search made in all databases resulted in a total of 363 articles. Applying the criteria for inclusion based on titles, abstracts and conclusions, 74 articles were selected for complete reading. After applying the exclusion criteria, the balance of items totaled in 38 relevant articles for this systematic review.

After the full reading of the articles found in the search, after applying the inclusion and exclusion criteria, the most relevant information contained in the articles was identified. The main proposal presented in each selected article was also verified.

III. RESULTS

The proposals presented in the selected articles were divided into: Framework, Architecture, Case Tools, Authoring Tool, Case Study, Ontology and Application.

The articles that propose a framework are those that define a software module or set of libraries, as in [6], or an extension to the digital television standard, such as [7], which defines an extension to MHP Multimedia Home Platform (MHP). MHP is a middleware developed by the Digital Video Broadcasting (DVB) Project [42].

An architecture is an abstraction that defines how educational services are distributed or developed, as is proposed in [1] and [8].

A CASE Tool was defined as a visual tool that helps developers create educational content, such as the proposals of [7], [9] and [2], which is developed in the Net Beans Platform. Authoring tools are important in t-learning because they allow educators to create interactive applications without knowing technical details for developing content for digital television platforms, such as programming [10].

In this context, six articles present the creation and development of an authoring tool to facilitate creation of content. Authoring tools have been proposed for the creation of courses and classes, as in [11], and also based on the SCORM standard, as in [12] and [13]. The latter presents a test of compliance with the proposed standard. None have conclusive tests on courses developed with the tool they propose.

In [14] an ontology based on the SCORM standard for learning objects is proposed. Concepts and semantic relationships are defined for the storage of information between programs and learning objects.

Some articles besides proposing an architecture or framework, also develop an interactive educational program to be used as a case study and testing of the proposal, such as in [15] and [16].

Table I and Fig. 1 summarize the different types of studies and implementations in the articles, divided by the focus given by the article, some appearing more than once in the table for having more than one proposal, for example: Case framework and tool [7] [9] [2].

<table>
<thead>
<tr>
<th>Article’s main focus</th>
<th>References</th>
<th>Number of articles</th>
</tr>
</thead>
<tbody>
<tr>
<td>Framework</td>
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<td>8</td>
</tr>
<tr>
<td>Architecture</td>
<td>[1],[8],[21],[22],[29],[30],[36],[37]</td>
<td>8</td>
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<tr>
<td>CASE tool</td>
<td>[2],[7],[9]</td>
<td>3</td>
</tr>
<tr>
<td>Authoring tool</td>
<td>[3],[10],[12],[13],[16],[23],[31]</td>
<td>7</td>
</tr>
<tr>
<td>Ontology</td>
<td>[14]</td>
<td>1</td>
</tr>
<tr>
<td>Application</td>
<td>[4],[19],[24],[29],[32],[35],[40]</td>
<td>13</td>
</tr>
</tbody>
</table>

Fig. 1. Main proposal presented in the article
Table II shows the articles divided by publication year. Fig. 2 shows the aggregate number of articles published on t-learning.

Table III e Fig. 3 shows the frequency of articles that present topics relevant to e-learning, namely usability and digital convergence. Besides these topics, use of e-learning standard, SCORM, and other digital television patterns were also considered, and are shown in detail in the next sections.

A. SCORM-Sharable Content Object Reference Mode

SCORM [17] is a set of standards and specifications for e-learning (distance education via web). The standard is developed by ADL (Advanced Distributed Learning) and defines a series of standards for accessibility, interoperability and reuse of learning content.

A tendency towards the use of this standard has been noted, with some articles focusing exclusively on the development of SCORM learning content for television. A total of 13 articles (36.11%) used the standard in some way in their proposals for t-learning. Table IV and Fig. 4 summarize the frequency of articles dealing with SCORM.

B. Interactive Digital Television Standards

There are several standards for digital television developed in different countries [18]. The most widely adopted standard is the DVB (Digital Video Broadcasting), present mainly in Europe, being used in about 60 countries, including European Union, Russia, India, Philippines, Malaysia, Saudi Arabia, Turkey, Vietnam, New Zealand, Australia, Iran. Also among popular standards is ATSC (Advanced Television Systems Committee), adopted mainly in the United States, Canada, Mexico, Guatemala, Honduras and South Korea. China adopts DTMB (Digital Terrestrial Multimedia Broadcasting) and Japan uses the ISDB (Integrated Services Digital Broadcasting). Brazil uses a new standard, the SBTVD (Brazilian Digital Television System), based on the ISDB standard, and it is beginning to see adoption in other countries of South America.

About 70% of the articles present research activities based upon the DVB standard, originating from the UK, Spain, Italy, France, China, Turkey and other countries. The Brazilian standard (SBTV) is employed in 16.67% of the studies, a total of 6 articles. All studies encompassing SBTVD were performed in Brazilian universities, with only one being executed in co-authoring with Canadian and French universities. No studies explicitly using any of the other iDTV standards were found. Table V and Fig. 4 summarizes the articles and the respective standard.
C. T-learning Motivations

There are several reasons to invest on television as a technology to assist in education. Due to its nature of entertainment, television provides an informal method of learning [19], assisting in the dissemination of knowledge and digital inclusion. Also, due to its attractiveness, education programs in iDTV gain advantages over educational videos [20], and they can be more related to real-world events, achieving a wider audience with the addition of interactivity [22]. With regard to interactive educational programs, it will be possible to reuse educational materials, e.g., lecture slides and videos, adding interactive elements and allowing new services based on educational materials to become available [19].

Besides these advantages, another advantage pointed out by the literature is that TVs easily support the transmission of video, without using expensive hardware, as in the case of video conferencing [3]. The non-abusive price of the devices and ease of interaction with other devices such as mobile phones and computers with internet are also positive factors for the development of t-learning experience, because it allows a continuous and ubiquitous learning (e-learning, t-learning and m-learning) [6].

T-learning, in almost all cases, was approached in a positive way, with the exception of [21], which states that interactive TV seems to replicate the traditional classroom where information is only transmitted by the teacher, not being able to interact with other students. This problem is also treated in other articles, which overcome the problem proposing the use of tools and frameworks for collaborative learning, for example, chat rooms, messaging, quizzes and other interactions through iDTV.

It is noticeable that the t-learning technology still has a number of questions unanswered, there is still need for more consistent testing, analysis of issues related to pedagogy, human-computer interaction, multimedia production, digital signal processing [16] and text entry via remote control. This last issue is commented about in some articles, due to the difficulty of entering text via the remote control, for example [22], [23] and [24]. In other articles [25] and [26], it is shown that this is not a problem and that users replaced the remote control with the use of the keypad of cellphones.

D. Validation studies

The performing of testing is important to validate the research and verify that the tool/application developed is user-friendly and error-free, among others attributes. Only one paper presented a methodology to validate its case study [21]. A larger part of the articles describes the validation as future work.

A total of 10 articles (25%) present tests throughout the work. Most perform tests related to the application interface, such as usability and accessibility, for example, in articles [11] [27] [28] [19] [25] [22]. The following tests reported in [28] [13] [29] [22] stand out due to the amount of details, diversity and number of users in the test. In [30] it is shown that the tests results were different according to the level of expertise in technology of the user, showing that the more experience in technology, the easier it is to use t-learning applications. Table VI and Fig.5 summarizes the frequency of tests applied in articles.

![Fig. 4. Digital Television standard used](image)

![Fig. 5. Distribution of validation studies](image)

<table>
<thead>
<tr>
<th>Tests results shown</th>
<th>References</th>
<th>Number of articles</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>[11],[13],[19],[21],[22],[25],[28],[30],[41]</td>
<td>11</td>
</tr>
<tr>
<td>No</td>
<td>[1]-[4],[6],[10],[12],[14],[16],[20],[23],[24],[29],[31]-[40]</td>
<td>27</td>
</tr>
</tbody>
</table>

By analyzing test results and lessons learned from articles, some recommendations for the usability of interactive applications can be highlighted.

Several articles recommend that the interactive application should not hide the main video program, a solution being to show the video in the corner of the screen in thumbnail view. Interactive applications should be intuitive [22] and it is important for the application not to be intrusive, since taking the user’s attention can be a negative factor [27].

Regarding the design, it is important for the development of the interface to be user-centered, as there is a gap regarding guidelines and style guides for iDTV [22]. To work around this problem, some articles use recommendations, style guides, and standards for web and desktop systems. As an example, in [25] the W3C recommendations for usability and accessibility were followed. In [28] usability testing was based on Jacob Nielsen, and in [22] style guides and usability tests for DTV, proposed by César A. Collazos, were used. Table VII and Fig. 6. summarizes the use of usability recommendations.

![Table VII](image)
The availability of a tutorial in the application, to provide guidance to the viewer, is of fundamental importance, since the iTDTV is a new technology for the user [22]. This tutorial can be made available in the form of a text or short video, for example.

Several articles commented on the importance of creating an environment relevant to the user’s context [10], [31], [11], [14], [16], [32], [22]. In [32], the importance of the “adaptive learning” is addressed: building an adaptive learning environment that takes into consideration the student’s progress during the interaction with the class/lesson.

Fig. 6. Use of usability recommendations

IV. DISCUSSION

T-learning is an approach that has been studied over the years and has been gaining momentum since 2006. Several applications, frameworks, architectures and authoring tools have been proposed to complement the teaching in an attempt to make this technology reach the viewer.

Digital inclusion is rarely addressed in the articles on t-learning, and is only mentioned in the introduction or review of literature, for example, in articles [33], [22], [16], [19] and [34]. The use of television is discussed as a tool for complementary education or informal learning, and is rarely regarded as a method to replace the teacher’s role.

The other environments, such as web (browsers) and mobile devices, are addressed as a tool to support teaching, as in [6], [35], [27] and [15]. Researches on convergent applications were also found, being produced for multiple devices, as in articles [36], [37] and [16].

The articles, mostly, mention a great potential for t-learning. Users and experts in education that use the systems presented in the studies pointed out that t-learning is a positive approach, and that it will assist education. There is still the need to improve tests by exploring real educational environments. The various proposals seen in this work show that t-learning through iTDTV can have a wide variety of development options and that it can aid distance education and can be, combined with e-learning, the key to digital inclusion and dissemination of knowledge for society.

A small amount of articles refers to the possibility of interaction using the return channel available on most DTV standards. This type of interaction tends to increase due to advances in technologies for Internet access and growth of televisions that allows this type of technology.

Much of what is produced, however, is still in the stage of evaluation and validation, and most productions are still in a prototype stage. Important is to mention that we could not identify a single study that described an experience that extrapolated the “limited laboratory experiment” status. In this context, we conclude that, although there has been a relevant and, at least during the last 4 years, constant amount of research in the area, t-learning as an educational option has still to grow to become a relevant field in the technology-supported education scenario.

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