Immersive Virtual Environments in Corporate Education and Training

Completed Research

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Abstract

The use of immersive virtual environments (IVE) in several areas has increased significantly in recent years, mainly due to lower costs, higher quality and increased availability of virtual reality (VR) tools and technology. Especially in formal education, numerous studies have shown positive learning outcomes of IVE. There is great potential to apply IVE solutions in training and corporate education. For those engaged in innovative, cost-effective and ergonomic new solutions for the field of corporate training and education, it is extremely valuable to understand the state of the art. However, so far, no study has consolidated this information. Thus, given the importance of the theme, this study seeks to organize and synthesize the results of studies published in this area. A total of 3516 studies were gathered and 12 selected for in-depth analysis and discussion, with the goal of providing a comprehensive review of technology, applications and trends.

Keywords

Immersive Virtual Environments, Corporate Education, Training, Virtual Reality.

Introduction

The concept of Virtual Reality (VR) has attracted enormous attention in recent years. Reasons for this development include the increase in ease of access (Martin-Gutiérrez et al. 2017; Rosedale 2017) and the declining cost of the equipment needed for content creation and visualization (Rasheed et al. 2015). The interest in applying virtual reality technology to education has existed since the inception of the technology in the 1960s (Dede 2010; Sutherland 1965; Winn 1993). However, the application of VR to professional and corporate training is more recent and has increased considerably in recent years (Ausburn and Ausburn 2008; Bhoir and Esmaeili 2015; Freina and Ott 2015; Li et al. 2011).

Faced with the scenario of constant changes in the corporate environment, companies need to continually invest in training and developing their employees to stay competitive and innovative (Lau and Ngo 2004; Riley et al. 2017). Studies indicate that investment in in-house training and corporate education show significant results with regard to employee performance and business innovation (Donate et al. 2016; Knowles et al. 2014; Minas et al. 2016; Stromquist and Monkman 2014; Sung and Choi 2014).
Regarding education, several studies on the use of immersive virtual environments (IVE) for higher education and for adults note the advantages of virtual environments compared to traditional teaching methods (Dalgarano and Lee 2010; Fowler 2015), especially in situations in which apprentices might be exposed to dangerous situations (Bailenson et al. 2008; Freina and Ott 2015).

After searching for literature reviews focused on the use of VR for training and corporate education using the keywords and online databases listed in the methodology section below, no reviews were found that addressed this precise topic; only related studies were found. Freina and Ott (2015) reviewed studies that used head-mounted-displays (HMD) for education in general; they concluded that few studies focused on corporate education. Other VR modalities, such as the Cave Automatic Virtual Environment (CAVE), desktop simulations or multiple screen displays were not considered in their review. Lee (2012) reviewed studies that used Augmented Reality in various educational or training settings. Regarding training, the author cites the use of AR as an auxiliary tool in the automotive assembly and industrial and military maintenance industries. Bhoir and Esmaeili (2015) reviewed papers and interviewed safety managers about the use of VR for construction safety training. They highlight the discrepancy between academics and practitioners, noting that only 7% of practitioners have considered using IVE in construction safety training. Jensen and Konradsen (2017) reviewed studies that used HMD in education and training. The authors conclude that HMDs are especially useful for developing motor skills, spatial and visual knowledge and affective skills. They affirm that the use of HMDs to pursue other learning goals and tasks is similar or less productive than the use of less-immersive technology or traditional instruction methods.

IVE can vary significantly depending on the devices used to set the environment (Biocca and Delaney 1995). CAVE and HMD are considered fully immersive VE because they can immerse more senses in the virtual environment (Biocca and Delaney 1995). This study focuses on technological aspects that are directly involved in the process of creating the perception of being in another reality. We call this "technological immersion", distinguishing it from other aspects, such as content, narrative and emotion, which are responsible for influencing the psychological perception of immersion. We considered multiple types of technological immersion, such as visual (single or multiple screens – with or without stereoscopy, HMD, or CAVE) (Biocca and Delaney 1995), auditory (flat sound – mono or stereo, or three-dimensional sound) (Jerald 2015), haptic (Hayward et al. 2004) and olfactory immersion (Murray et al. 2016).

Considering the recent increase in the use of VR in corporate education, this paper presents – in addition to training applications and many other applications and results – a proposal for a systematic review of Immersive Virtual Environments applied to Training and Corporate Education.

The objectives of this systematic literature review are as follows: 1. To identify the domains, themes and technologies used for researching the use of Immersive Virtual Environments in Corporate Education and Training; 2. To identify study limitations, existing gaps in knowledge of the topic, and research opportunities.

**Research Methodology**

**Research Questions**

The study proposed here aims to answer the following research questions, all of which pertain to Immersive Virtual Environments in Training and Corporate Education:

1. What types of VR technological immersion are used?
2. What are the industries, areas of application and topics addressed?
3. What are the limitations, gaps and suggestions for future studies as reported by the authors?

**Search Strategy**

**Search Terms**

To conduct a search for studies on the use of Immersive Virtual Reality in corporate education, the main terms identified after a brief exploratory research and used for the search were: **Virtual Reality, Education** and **Business**. For each term, "synonyms" or related terms were also included in an effort to expand the range of studies in the search:

**Virtual Reality**: 360 video, immersive video.
Immersive Virtual Environments in Corporate Education and Training

**Education**: learning, teaching, training, instruction, knowledge.

**Corporation**: business, professional, company, enterprise.

The search key thus used the following string, composed of Boolean operators (AND/OR): (["Virtual Reality" OR "360 video" OR "immersive video"] AND ["learning" OR "teaching" OR "training" OR "instruction" OR "knowledge"] AND ["corporation" OR "business" OR "professional" OR "company" OR "enterprise"]). When the search field was of limited size, the search key was split into multiple fields using the advanced search option and keeping the same logical value. When the advanced search option was not available, the multiple searches using broader sub strings were performed and the results combined, keeping the same logical value of the original search string.

**Online Databases**

Databases were selected to cover the main domains related to the study of the use of immersive environments in training and corporate education, such as Information Systems, Administration, Education, Engineering, Computing, Pedagogy and Psychology. Consequently, the databases selected were the following: ERIC, Scopus, ACM Digital Library, Springer, Science Direct and IEEE Xplore (already indexed by Scopus).

In addition, the Association for Information Systems (AIS) journal basket list (Lowry et al. 2013) was considered. The following journals were searched: European Journal of Information Systems, Information Systems Journal, Information Systems Research, Journal of AIS, Journal of Information Technology, Journal of MIS, Journal of Strategic Information Systems, MIS Quarterly. The European Journal of Information Systems and Journal of Information Technology are indexed by the Springer Database and thus automatically covered by the search in Springer. For each of the other journals, an exclusive search was performed using the same search string. The number of papers resulting for each database and journal is presented in Table 1.

<table>
<thead>
<tr>
<th>Datasource</th>
<th># Papers found</th>
</tr>
</thead>
<tbody>
<tr>
<td>ERIC</td>
<td>2007</td>
</tr>
<tr>
<td>Scopus</td>
<td>772</td>
</tr>
<tr>
<td>ACM Digital Library</td>
<td>630</td>
</tr>
<tr>
<td>Springer</td>
<td>28</td>
</tr>
<tr>
<td>Science Direct</td>
<td>10</td>
</tr>
<tr>
<td>Information Systems Journal</td>
<td>9</td>
</tr>
<tr>
<td>Information Systems Research</td>
<td>14</td>
</tr>
<tr>
<td>Journal of AIS</td>
<td>14</td>
</tr>
<tr>
<td>Journal of MIS</td>
<td>26</td>
</tr>
<tr>
<td>Journal of Strategic Information Systems</td>
<td>5</td>
</tr>
<tr>
<td>MIS Quarterly</td>
<td>1</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>3516</strong></td>
</tr>
</tbody>
</table>

**Table 1. Database search results**

The articles not available through institutional access were requested from their respective authors; those that were requested were also selected based on the inclusion and exclusion criteria.

**Inclusion criteria**

The criteria for including studies in this review were as follows:
- Peer-reviewed articles published in English; and
- Containing the description of the business area of application; and
- Containing the description of the area of knowledge addressed; and
- Describing the methodology and results of the application in the company; and
- Based on primary or secondary data; and
- At levels 1 to 4 in the hierarchy of evidence described in (Kitchenham 2004).

**Exclusion Criteria**

Documents found in searches of the following categories were excluded: Books, Book Chapters, Reports, Dissertations, Theses, Guides or Viewpoint articles / papers (level 5 in the hierarchy of evidence).
(Kitchenham 2004). Furthermore, studies describing a tool or a potential tool, but with no results and no application in a company, were excluded. Likewise, those in which a system was proposed but not tested, and in which no results were provided, were excluded. In addition, studies involving IVE for business education targeting only education institutions were excluded. Finally, studies not answering the research questions were excluded.

**Search Flow**

![Flowchart](image)

**Figure 1. Search Flow**

**Data Extraction Form**

After the search and application of all the inclusion and exclusion criteria, the papers selected were reviewed and the relevant information was extracted. It is worth noting that in order to provide a more complete picture of the publications, more information was gathered than was needed to answer the research questions. The following information was extracted: Year of publication, Country of origin of the research, Periodical or Event whereby the research was published, Experimental Design (experimental, quasi-experimental, non-experimental, correlational, observational), (Number, Age and Education), Sessions (Quantity and duration), Research environment (laboratory, classroom, other), Research duration, Equipment used, Characteristics of the materials used (media or not), Area of knowledge covered, Area of application (manufacturing, sport, business, medicine, engineering, etc.), Topic addressed, Type of knowledge addressed (conceptual, procedural or both), learning outcomes, learning assessment results, research limitations identified by the authors, future studies suggested by the authors, and bibliographic references used by the authors.

**Evaluation and Quality Assurance**

The search was conducted by two researchers who applied all the criteria for inclusion and exclusion to select the articles that were part of this review. Consensus was sought in situations in which there was divergence in the selection of articles.

**Results and Discussion**

This systematic review of the literature considered 3516 studies. These studies were initially reviewed through the review of titles and abstracts, whereby the applicability of the inclusion and exclusion criteria described in the research methodology section were verified. In cases in which the review of the abstract was not conclusive for applying the exclusion or inclusion criteria, the article was read in its entirety.

After the application of the criteria, 163 articles remained for categorization. Thus, to place these articles in the categories described, the articles were read in their entirety. Still, at this stage, 151 articles were excluded because they had fallen into any of the exclusion criteria. Many papers were related to Healthcare Procedure Training in Hospitals, but they were not included because of their nature. Additionally, many papers found described applications of VR in Business and Corporations, but they were not tested in a Business or Corporate setting, so they were not included either.
After applying the criteria, only 12 articles remained. Of these, only 2 (17%) studies were found in the ERIC database, while the remaining 10 (83%) were found in the Scopus database. No study in the ACM databases Digital Library, Springer, Science Direct or IS Journals remained among those included after applying all the criteria.

The following sections present the answers to the survey questions according to the data found.

**IVE Technological Immersion**

The most widely used visual technological immersion is single screen (such as a television or desktop monitor), with 75% of the studies using this approach (including 8% stereoscopic and 8% with stereoscopic glasses). The remaining 25% of the studies used HMD visual immersion. As HMD has become more cost-effective, and considering the fast and cost-effective development of content for IVE (Armstrong 2017; Rosedale 2017), as 360-degree videos can be easily created using 360-degree cameras, the number of studies using this setting is expected to increase in the coming years.

Few studies described the type of auditory immersion used, and the ones that did reported the use of flat sound (mono or stereo). None used 3D (three-dimensional) auditory immersion. Only 17% of the studies used haptic immersion. The results are shown in Tables 2 and 3.

<table>
<thead>
<tr>
<th>Visual</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single-screen</td>
<td>58</td>
</tr>
<tr>
<td>Head-Mounted Display</td>
<td>25</td>
</tr>
<tr>
<td>Single-screen with stereoscopic glasses</td>
<td>8</td>
</tr>
<tr>
<td>Single-screen stereoscopic</td>
<td>8</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Auditory</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flat sound</td>
<td>33</td>
</tr>
<tr>
<td>No description</td>
<td>67</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Haptic</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Haptic</td>
<td>17</td>
</tr>
<tr>
<td>None</td>
<td>83</td>
</tr>
</tbody>
</table>

Table 2. Visual Technologies

Table 3. Auditory and Haptic VR Technologies

The use of technological immersion seems to be underexplored. The prevalence of visual immersion may be due to the comparative advantage of IVE (over other instructional methods) in presenting visual content (Bowman and McMahan 2007; Raja et al. 2004; Schuchardt and Bowman 2007). Albeit scarce in the context of training and corporate education, studies focusing on IVE for learning in formal education showed positive outcomes of auditory and haptic immersion (Dede et al. 1999), especially for motor skill development (Richard et al. 2006; Sigrist et al. 2013). This sheds light on the future use of IVE in training and corporate education.

**Industry, area of application and topics addressed**

The industry with the most studies using IVE in training and corporate education is Construction, with 25%, followed by Energy and Aerospace at 16.5% each. Safety is the area of application with the most studies, at 33%, followed by knowledge management and communication, with 16.7% each. The results are presented in Tables 4 and 5.

<table>
<thead>
<tr>
<th>Industry</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Construction</td>
<td>25</td>
</tr>
<tr>
<td>Energy</td>
<td>16.7</td>
</tr>
<tr>
<td>Aerospace</td>
<td>16.7</td>
</tr>
<tr>
<td>Mining</td>
<td>8.3</td>
</tr>
<tr>
<td>Fashion</td>
<td>8.3</td>
</tr>
<tr>
<td>Tourism</td>
<td>8.3</td>
</tr>
<tr>
<td>Engineering</td>
<td>8.3</td>
</tr>
<tr>
<td>Multiple</td>
<td>8.3</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Area of Application</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Safety</td>
<td>33.3</td>
</tr>
<tr>
<td>Knowledge Management</td>
<td>16.7</td>
</tr>
<tr>
<td>Communication</td>
<td>16.7</td>
</tr>
<tr>
<td>Customer Service</td>
<td>8.3</td>
</tr>
<tr>
<td>Project Risk Management</td>
<td>8.3</td>
</tr>
<tr>
<td>Manufacturing</td>
<td>8.3</td>
</tr>
<tr>
<td>Multiple</td>
<td>8.3</td>
</tr>
</tbody>
</table>

Table 4. Studies per industry

Table 5. Areas of application

The results corroborate the statement that IVE is especially recommended for simulating situations in which real exposure is impossible, potentially dangerous (Bailenson et al. 2008; Freina and Ott 2015) or costly (Bailenson et al. 2008). The Construction, Energy, Aerospace and Mining industries involve dangerous situations (in some job tasks) and expensive in-place training; hence, the use of IVE for training...
in these industries can prevent risks to the learners and important losses in the case of initial under-performance during training.

In this sense, safety seems to have the greatest appeal for IVE use and is therefore the most frequent application studied so far. Some studies address the use of IVE to collect tacit knowledge and the use of data to enhance organizational learning. Another frequent application of IVE is the development of communication skills, probably because IVE allows iterative practice, the receipt of immediate feedback, and the avoidance of social judgment (Lau 2015; Na and Weihua 2012). Table 6 presents the topics addressed in each area of application.

<table>
<thead>
<tr>
<th>Industry</th>
<th>Area of Application</th>
<th>Topics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aerospace</td>
<td>Safety</td>
<td>Flight training (Mavin and Roth 2015)</td>
</tr>
<tr>
<td></td>
<td>Manufacturing</td>
<td>Welding (Choquet 2008)</td>
</tr>
<tr>
<td>Construction</td>
<td>Safety</td>
<td>Safety planning (Azhar 2017)</td>
</tr>
<tr>
<td></td>
<td>Knowledge Management</td>
<td>Tacit knowledge collection for Asphalt Compaction (Vasenev et al. 2013)</td>
</tr>
<tr>
<td></td>
<td>Risk Management</td>
<td>Offsite Production (Goulding et al. 2012)</td>
</tr>
<tr>
<td>Energy</td>
<td>Knowledge Management</td>
<td>Tacit knowledge collection for Electricity Plant / Maintenance workflow (Haase et al. 2013)</td>
</tr>
<tr>
<td></td>
<td>Safety</td>
<td>Oil &amp; Gas Plant Safety (Gagliati et al. 2011)</td>
</tr>
<tr>
<td>Engineering Solution</td>
<td>Communication</td>
<td>Product and Solution Sales Knowledge (Yap and Børn-Andersen 1998)</td>
</tr>
<tr>
<td>Provider</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fashion</td>
<td>Customer Service Management</td>
<td>Customer relationship, communication skills, crisis management, product knowledge (Lau 2015)</td>
</tr>
<tr>
<td>Multiple</td>
<td>Multiple</td>
<td>Multiple (Taylor and Chyung 2008)</td>
</tr>
<tr>
<td>Mining</td>
<td>Safety</td>
<td>Blasting works (Grabowski and Jankowski 2015)</td>
</tr>
<tr>
<td>Tourism</td>
<td>Communication</td>
<td>Communication skills, knowledge of touristic places (Na and Weihua 2012)</td>
</tr>
</tbody>
</table>

Table 6. Industry, Area of Application and Topics addressed

Suggestions of Future Studies

Studies using IVE in the Construction Industry suggest the use of IVE to provide safety training to university staff and students (Azhar 2017). Vasenev, Hartmann, & Dorée (2013), in their study of the use VR applications to train machine operators performing asphalt compaction to increase pavement quality, suggest that future studies using VR environments with more than one operator should obtain additional information about how machine operators collaborate during the compacting process. The authors also suggest the development and use of a serious multi-user gaming environment for the proposed application (Vasenev et al. 2013). Goulding et al. (2012) highlights the need to consider time and resources prior to developing an IVE in order to address the multiple stages and impacts of the construction project and the use of a multi-user environment.

Regarding the Aerospace, Electricity and Mining Industry, Mavin and Roth (2015) recommend further studies to consider the requirements of particular workplaces for optimal learning environments. Grabowski & Jankowski (2015) suggest a statistical analysis of mine accidents before and after the use of VR safety training as a way of assessing the influence of VR training on the number of occupational accidents (Grabowski and Jankowski 2015). Haase et al. (2013) highlight the need to improve user feedback to increase motivation. In addition, studies should be conducted that aim to hasten the process of knowledge investigation using IVE and that aim to develop more exploratory and experiential learning tasks (Haase et al. 2013).

Within the area of customer service management, Lau (2015) suggests studies involving learning and blended learning communities. The author suggests further investigations into the field of organizational learning distributed in stereo3D VR. He argues that a new era in organizational learning is yet to come given the new generation of employees who have encountered virtual technologies, communication and telepresence activities (Lau 2015).
Limitations and Future Work

Although the methodology used in this systematic review aimed to identify and analyze the most important studies on the use of IVE in training and corporate education, this systematic review has some limitations. One of the goals of this work was to identify studies reporting results of real-world applications of IVE to training and corporate education; however, many of these studies and results may not be available to the public and are kept confidential within companies. Therefore, the extent of the application of IVE to training and corporate education cannot be evaluated by academic publications alone.

We identified a lack of studies using IVE for training and corporate education in many industries that could benefit from IVE, such as food, chemicals, furniture, pharmaceuticals and services (including maintenance and utilities). In future works, we suggest using more rigorous experiments with control groups, effectiveness evaluation, multi-user environments and longitudinal studies. Research shows that the results obtained in VR Educational settings tend to be more positive when the experimental design is not so rigorous (Slavin and Smith 2009). Additionally, a meta-analysis of the current studies could provide important insights and directions for further research.

Another gap concerns the fact that many studies described interesting concepts for VR that could be applied to Corporate Education. In fact, a number of those studies were designed precisely for that purpose. However, the vast majority were excluded because they were not used in a real-world corporate setting. Some were tested by students, not real practitioners. Hence, those studies should be extended to experimental settings in real corporate environments with real professionals using VR; this approach could produce more realistic results. Finally, there were few studies reporting real industry practitioners’ feedback on the design of the solution, and this can be considered another important gap.

There may still be important barriers to VR adoption for training and education in Corporations. The adoption barrier could be related to the high cost of establishing VR environments and of developing content, in addition to the lack of professionals with the right skills to develop such solutions. Another barrier could be related to the low number of off-the-shelf, ready-to-use platforms that are appropriately suited to real corporate needs and to each company specifically. When people want an immersive environment for training, the requirements for realism may ascend to a higher level, resulting in the need for tailor-made solutions. More research is needed to understand the reasons for this low adoption rate.

Considering IVE technological immersion, future studies could use auditory, haptic and olfactory immersion and evaluate the effectiveness of these approaches. For example, temperature and olfactory feedback could be used in fire and safety training in different industries, such as chemicals and pharmaceuticals. Force feedback could be used in machine maintenance and assembly training in the manufacturing industry.

Conclusions

The goals of this systematic review of the literature were to 1. Identify the domains, themes and technologies used for researching the use of Immersive Virtual Environments in Corporate Education and Training; 2. Identify limitations, existing gaps and research opportunities. In this context, 12 scientific studies were selected out of the 3516 first considered; these studies reported the use of immersive virtual environments in training and in corporate education in order to outline the studies published on the subject. The exclusion of such a large number of studies was attributed to a combination of factors: (1) many studies misused the terminology, (2) many studies were proposed but not tested in corporate settings and (3) many studies were focused on healthcare.

A heterogeneous distribution was identified among the types of technology used to create the technological immersive virtual environment; the use of single-screen for visual immersion was dominant, and none of the studies used 3D auditory immersion, probably because single-screen and flat sound are more available and less expensive than the other IVE setups. Considering the pace of technological evolution and increasing cost-effectiveness, an increase in the use of HMD and Cave-like IVE, as well as in 3D auditory immersion, is expected.

The most frequent applications were in the civil construction, energy, aerospace and mining industries. These industries have in common the importance of safety training and the high cost of errors (life and capital). These factors could have increased companies’ interest and adoption of IVE in training. Some
studies were found in the engineering, tourism and fashion industries. Considering the need for technologies to fit the task at hand, further research is needed to test if (and how) other industries could take advantage of using IVE in corporate training.

The main application area found was safety training, which is logical given the need to avoid exposing humans to real danger. In addition, other application areas were Knowledge Management, Communication, Customer Service, Project Risk Management, and Manufacturing. Although the diversity of applications and industries shows the flexibility and potentially wide scope of the applications of this technology, it also shows the potential for more research and new applications in many unexplored industries and domains.

Few gaps were reported by the authors of the articles, probably because this is a relatively new area of VR application and, therefore, there are many gaps to be investigated. We identified some important gaps, as there is a lack of research in the following areas: (1) areas other than safety, (2) factors considered in the decision of whether to implement an IVE training program, (3) evaluations of the effectiveness of IVE training, (4) the technology-task fit of IVE.

As a suggestion for future studies, the authors of the papers reviewed suggest developing applications for production planning and training, in addition to remote maintenance. Additionally, they emphasize the importance of evaluating the effectiveness of the use of IVE in training through performance metrics.

Considering that many papers described but did not test applications of IVE in Business and Corporations, we expect, in the years to come, an increase in studies testing these applications, and we see this as an important research opportunity. Beyond training in safety and other technical skills, there are many corporate training applications of IVE, such as Orientation and Onboarding training, Soft Skills training, product and service training and mandatory training (i.e., that required by laws and regulations).

As there are few studies using IVE in corporate training, this review poses some questions: (1) will other industries benefit from using IVE in corporate training compared with the current training methods used? (2) which tasks can benefit most from training in IVE? (3) What factors should a company consider when implementing IVE training? (4) Which frameworks and models should be considered when using IVE in corporate training?

We conclude that studies on the use of IVE for Training and Corporate Education are still incipient, likely because the technology for creating IVE was not very accessible until recently and because some studies carried out in the corporate sphere are not published in scientific vehicles. Thus, this is a promising avenue for research, especially with the increasing accessibility of both technology and content development for IVE. Those factors have the potential to increase the number of studies on this topic, mainly because of potential partnerships between companies and educational institutions.

REFERENCES


