# THE CLASSIFICATION OF AUGMENTED REALITY BOOKS: A LITERATURE REVIEW

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## Abstract

The technological revolutions having occurred in many areas also had an impact on books, and electronic books emerged. However many problems have emerged in the availability of electronic books, and users have started to return to books that are tangible, with pages of which they can physically turn. Augmented reality books are prepared by enhancing these books attractively by introducing interactive and immersive properties into the superficial and interaction-free characteristics of printed books. While augmented reality books maintain the advantages and philosophy of printed books, they introduce an innovative approach to printed books with a static and non-interactive structure by adding various sensorial interactions. The aim of this study is to find and analyse all augmented reality books of academic nature prepared in the field of education through the literature review technique. Firstly, the term augmented reality is defined and the reflections of the augmented reality applications in the field of education are reviewed. Then the types of the augmented reality books are determined and all the augmented reality book studies present in the literature and of academic nature are listed. While the books are listed, they are arranged by year and the technologies used are identified. It is seen that no such classification has been made in the literature before this study. Through this original study, all the previous studies are tabulated in order for it to be guiding for other researchers in this field and the present situation is revealed in the context of development of these books.

Keywords: Augmented reality, virtual reality, mixed reality, augmented reality books, printed books.

## 1 INTRODUCTION

Sources state that [1] [2] the printed book revolution started upon the introduction of the first modern printing press by Johannes Gutenberg, who is indicated to be one of the most influential people of the past 1000 years. Upon this invention which changed the course of history and allowed for the reproduction and more rapid dissemination of information, books reached a crucial position. Particularly, having become an indispensable part of education, books have undergone various changes and transformations over years. Augmented reality books are prepared by enhancing these books attractively by introducing interactive and immersive properties into the superficial and interaction-free characteristics of printed books. Enhanced through augmented reality technology and introducing an additional value to printed books, these books are one of the most remarkable areas of use of augmented reality in education [3].

After the concept of augmented reality and its areas of use in education are briefly described within the scope of this study, augmented reality books are mentioned; the differences of these books from mixed reality and virtual reality books are discussed; augmented reality and mixed reality books, which have been prepared up to 2014 are tabulated and analysed; and a conclusion is reached with respect to the changes having occurred over years.

## 2 THE DEFINITION OF AUGMENTED REALITY

Augmented reality (AR) is a technological approach which enables that the real and the virtual be viewed in the same place by supporting the real world with 3D virtual objects and enhances the user perception [4]. AR applications can be used in many different platforms such as desktops, notebooks and mobile devices [5]. AR applications can also be used in monitor based systems, see-through and video see-through head mounted displays and projection-based spatial systems [6].

## 3 AUGMENTED REALITY IN EDUCATION

It can be seen that studies in the field of education on AR, which can be used in a wide range of areas, have gained momentum in recent years. The use of AR in education ensures users make sense of complex contents in a more effective manner, enhances engagement and supports learning through immersive contents [7]. Compared to traditional and superficial displays, AR has some advantages in developing spatial abilities and strengthening cognitive abilities [8]. AR in the educational sense facilitates students' learning of abstract concepts by providing contemporary settings [9]. The areas of use of AR in educational settings are indicated as AR books, AR gaming, discovery-based learning, skills training and object modelling [10]. One of the most interesting uses in recent years among the promising educational applications are AR books [5].

## 4 TYPES OF AUGMENTED REALITY BOOKS

In today's educational settings, printed books are one of the indispensable components for learning processes [11]. People still prefer books due to their properties such as physical presence (tangibility), possession, and the high quality of printed material [12]. Books are known as a format used to convey information to the learner thanks to their properties of simplicity and flexibility in all periods [13]. The efforts to transform and develop physically printed books, papers and other printed materials have continued over the years. Many types of books such as audio books, multimedia CD ROM books, online books, electronic books, where the digital elements are incorporated into traditional printed books and they are tried to be enhanced, have been developed [14]. According to Margetis et al., in the present situation printed books and electronic books are still controversial both in a general sense and in an educational sense [11]. Although in our age numerous technologically innovative educational materials have been developed, it can be seen that printed books are not abandoned. An immersive, interactive and active learning platform can be created by applying AR technology to printed books, where despite their many superior aspects, information is provided in a static and non-interactive manner.

Multisensory, visual, auditory and haptic experiences are introduced adding multimedia contents to the printed material [12]. When looking at any of the AR books, it is not seen as different from any ordinary physical printed book [15]. However, when this book is viewed with customised devices specific to it such as smart glasses, head mounted displays, mobile device cameras or cameras integrated into desktops, the auditory insertions are provided; 3D virtual animations move on the book; the printed book is enhanced through various interactions involving the five senses and made interesting. Thus, the user motivation is also positively affected. It can be seen that there have been studies where AR books have been made more powerful by incorporating various interactions such as 3D magnetic trackers, foldable cubes, paddles, gaze tracking, mouse clicks, and turntables with a slide device into them [12].

Augmented reality books are used with different terminologies in various studies. While in some studies these terms are interchanged, in other studies they bear a completely different meaning. Before reviewing augmented reality books, the differences between the concepts virtual reality, augmented reality and mixed reality need to be identified.

Milgram and Kishino made some classifications with respect to reality and virtuality [16]. First, they placed the real environments involving the physical world at the leftmost of the continuum. They put the virtual environments consisting of completely artificial and synthetic components at the opposite side, and placed the augmented reality (AR) and augmented virtuality (AV) in the middle of these. While AR refers to making virtual and digital enhancements to the physical reality, AV is performed by adding real world elements to the virtual environments. There is also mixed reality (MR) as an umbrella concept involving AR and AV and including the elements belonging to the real and virtual environments at the topmost of Milgram and Kishino's reality-virtuality continuum. In this context, it can be said that AR involves the real environments much more than it does the virtual environments. Virtual reality (VR) is performed in completely digital and virtual environments in contrast to AR.


Figure 1: Reality-virtuality continuum
Source: "A Taxonomy of Mixed Reality Visual Displays" by Milgram and Kishino [16].

Following this separation between AR, VR and MR, some studies where this continuum is adapted in terms of book augmentation are performed.

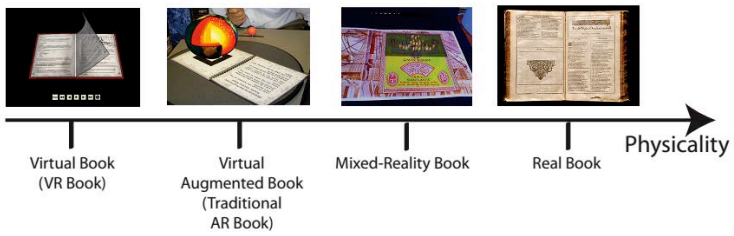


Figure 2: The physicality continuum
Source: "The Design of a Mixed-Reality Book: Is It Still a Real Book?"
by Grasset, Dünser and Billinghurst [17].

The *physicality continuum* [17] figure was prepared by Grasset, Dünser and Billinghurst drawing upon Underkoffler and Ishii's *continuum of object meanings* [18] and Milgram and Kishino's *reality-virtuality continuum* [16].

Accordingly, virtual books (VR books) are books completely prepared in an electronic format and involving minimum physicality. Traditional AR books are used by adding virtual elements to physical books. Mixed reality books (MR books) are composed of virtual insertions at the meaningful level in the most analogous manner to physical books [17].

## 5 METHODOLOGY

In this study, it is aimed that all the augmented reality books present in the literature and indexed in the databases until 2014 be identified, all the related studies be listed and the present situation be detected. In this context, academic social networks such as Researchgate, Mendeley are used as well as databases such as Ebscohost Discovery Service, Google Scholar, ERIC, Social Science Citation Index (SSCI), IEEE Xplore Digital Library, Taylor & Francis Online, ProQuest, Wiley Online Library, Science Direct, IGI Global, SAGE, ACM Digital Library, Springer. In the databases reviewed, the studies are accessed through the searches done with words such as *augmented reality books, mixed reality books, virtual reality books, augmented books, 3D pop-up books, augmented reality interactive books*. All the academic studies such as any books, articles, proceedings relating to augmented reality books are reviewed and listed. "The related work" sections in the studies acquired is also taken into account and the appropriate ones are added to the table. Then duplicate studies are determined and eliminated, and the final table is prepared.

The table does not include commercial AR books and VR books with a completely virtual approach and academic examples such as WebBook [19], 3Book [20] and IE Book [21]. The commercially developed books generally involve a game-based approach in order for small children to like reading books. However, under this study the academically developed AR books are preferred rather than the commercial AR books. Only AR books and MR books are reviewed under this study and tabulated by years. While identifying, the entire study is scrutinized and the category in which the book belongs is determined and placed in the table.

## 6 FINDINGS

Some conclusions are reached as a result of the literature review and content analysis conducted. 46 augmented book studies are found and it was determined that the augmentation studies for printed

materials are not such a new approach. The idea of digitally augmenting the physical paper has started in early 90s with DigitalDesk [22] and the successor goes forward with EnhancedDesk [23]. These studies are of importance for constituting the first fundamental structure in the change and transformation process having occurred towards augmented desk, 3D pop-up books since they are one of the first studies in the field.

46 augmented book studies identified are classified as *AR book, augmented desk/paper augmentation approach, 3D pop-up book, tangible AR approach and MR book*. 8 studies are determined to have been prepared as MR books and 38 studies are determined to have been prepared as AR books.

Table 1: Classification of augmented reality books by their types.

| **Authors (Year)** | **Book Name (if any)** | **Category of Technology Used** |
|---|---|---|
| Wellner (1993) [22] | DigitalDesk | AR (Augmented Desk/Paper Augmentation) |
| Kobayashi and Koike (1998) [23] | EnhancedDesk | AR (Augmented Desk/Paper Augmentation) |
| Forsberg et al. (1998) [24] | ErgoDesk | AR (Augmented Desk/Paper Augmentation) |
| Billinghurst et al. (2001) [15] | Magic Book | MR (MR Book) |
| Kawashima et al. (2001) [25] | Magic Paddle | AR (AR Book)/Tangible AR Approach |
| Back et al. (2001) [26] | Listen Reader | AR (AR Book) |
| Anoto (2002) [27] | Anoto | AR (Augmented Desk/Paper Augmentation) |
| Mackay et al. (2002) [28] | A-Book | AR (AR Book) |
| Saso et al. (2003) [29] | Little red | MR (MR Book) |
| McKenzie and Darnell (2003) [7] | EyeMagic Book | AR (AR Book) |
| Gomez (2003) [30] | Dimensional Reading Project | AR (AR Book) |
| Luff et al. (2004) [31] | Paper++ | AR (Augmented Desk/Paper Augmentation) |
| Singh et al. (2004) [32] | AR Comic Book | AR (AR Book) |
| Woods et al. (2004) [33] | AR Volcano Kiosk | AR (AR Book) |
| Hirooka and Saito (2004) [34] | - | AR (AR Book) |
| Shibata et al. (2004) [35] | Vivid Encyclopedia | MR (MR Book) |
| Ucelli et al. (2005) [36] | The Book of Colours | AR (AR Book) |
| Tallyn et al. (2005) [37] | - | AR (Paper Augmentation) |
| Holman et al. (2005) [38] | PaperWindows | AR (Paper Augmentation) |
| Gupta and Jaynes (2006) [39] | Universal media book | MR (MR Book) |
| Dünser (2007) [40] | AR Jam | AR (AR Book) |
| Cho et al. (2007) [41] | - | MR (MR Book) |
| Oliveria et al. (2007) [42] | LIRA | AR (AR Book) |
| Dünser and Hornecker (2007) [43] | - | AR (AR Book) |
| Taketa et al. (2007) [44] | Virtual Pop-up Book | AR (AR Book)/3D Pop-Up Book |
| Grasset et al. (2007) [45] | The Mixed Reality Book | MR (MR Book) |
| Liao et al. (2008) [46] | PapierCraft | AR (Augmented Desk/Paper Augmentation) |
| Dünser (2008) [47] | - | AR (AR Book) |
| Scherrer et al. (2008) [48] | Haunted book | AR (AR Book) |
| Grasset et al. (2008) [14] | The House That Jack Built | MR (MR Book) |
| Wu et al. (2008) [49] | WikiTUI | AR (AR Book)/Tangible AR Approach |
| Yang et al. (2009) [50] | - | AR (AR Book) |
| Dias (2009) [51] | miBook | AR (AR Book) |

| | | |
|---|---|---|
| Martin-Gutierrez et al. (2010) [6] | AR Dehaes | AR (AR Book) |
| Sin and Zaman (2010) [52] | Live Solar System (LSS) | AR (AR Book)/Tangible AR Approach |
| Ha et al. (2011) [12] | Digilog book | AR (AR Book) |
| Vate-U-Lan (2011) [53] | The Seed Shooting Game | AR (AR Book)/3D Pop-Up Book |
| McGrath et al. (2011) [54] | AR Etnobotany Workbook | AR (AR Book) |
| Kirner et al (2012) [5] | GeoAR | AR (AR Book) |
| Jeong et al. (2012) [55] | Live Book | MR (MR Book) |
| Okawa et al. (2012) [56] | SOLRA | AR (AR Book) |
| Vate-U-Lan (2012) [13] | The Seed Shooting Game | AR (AR Book)/3D Pop-Up Book |
| Margetis et al. (2013) [11] | SESIL | AR (Augmented Desk/Paper Augmentation) |
| Correa et al. (2013) [57] | AGeRA | AR (AR Book) |
| Vinumol et al. (2013) [58] | Protype | AR (AR Book) |
| Mahadzir and Phung (2013) [59] | - | AR (AR Book)/3D Pop-Up Book |

Within the scope of the study, it was observed that there have been studies where augmented reality and mixed reality books are interchanged. It is concluded that they are not mostly separated from each other with rigid lines. Researchers tended to move away from the *augmented desk/paper augmentation* approach over the years and game-based children's books called *interactive 3D pop-up books* are focussed on in recent years. Also a tendency against special glasses and head mounted displays prepared to view the books and towards web cameras integrated to desktops and mobile devices were observed. Another situation noticed when analysing the studies is that most augmented book studies are not prepared by a single author, and the development of augmented reality books are supported by certain organizations.

## 7 CONCLUSION

While technological advances have affected the social and cultural structures of societies, they have also had reflections on education and changed the structures and functions of education tools. In this context, a change in book reading habits of digital era societies may be observed. Nowadays the technological advances having occurred in the field of education progress to enhance and improve the effectiveness of the former understandings rather than completely removing them. While the teaching technologies and course materials have become so varied and advanced, the course materials are not abandoned. While books are old, deep-rooted and powerful learning tools, they need to be developed in some aspects and be able to keep up with the technological advances in our age. Integration of a new technology into an old environment may have more positive or more negative effects. As a result of many studies conducted, this combination in augmented reality books has created a new synergy and had a positive effect among learners.

Through this study, all the augmented reality books prepared in an academic sense until 2014 are identified and classified. The literature review indicates that no such classification has been made for augmented reality books before this study. Thus, the present situation in the field is identified and an analysis guiding future researchers is presented.

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