Work-in-Progress–the ARI^{2}VE Model for Augmented Reality Books

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***Abstract*— In this work-in-progress paper, the first attempt of the ARI^{2}VE model for Augmented Reality books is presented. The components of the model are based on research on instructional design and multimedia learning as well as previous implementations of AR in books. The components interaction, interplay, visualization and engagement are described in detail and illustrated with an example. Due to the early stage of the model no empirical findings can be reported yet, but first investigations are in progress. A call for international cooperation and joint research is made.**

Index terms— augmented reality, ar books, instructional design, multimedia learning, ar learning environment

I. Introduction

Research on Augmented Reality (AR) in education is currently an absolute trend, which can be seen, for example, in the increasing number of publications in recent years [1]. One variant of AR-supported learning has been discussed for a long time, namely the possibility of using AR to add interactive and virtual objects to classical paper-based books [2], [3]. These include videos, audios, simulations, 3D objects, and animated characters, which act as educational agents that accompany children through a story [4] or contribute to a better understanding of chemical compounds [5]. Interactions are realized in a variety of ways, such as paper paddles with markers, which become protagonists of the story via AR and thus enable readers to actively intervene in the storyline [6]. It is also possible to place such markers directly on the pages of the book, which in turn leads to a different presentation of the page contents [7].

By actively intervening during reading, a completely new reading experience can be created, especially for younger learners, which can have a positive effect on the motivation, satisfaction, memory, and understanding of the presented content [8]–[10]. When learners design their AR books, this is also perceived as an exciting and joyful task [11] and can promote digital literacy skills [12].

Often, however, the publications mentioned above refer exclusively to constructivist methods, such as explorative and situated learning. Younger and less experienced learners can quickly become overwhelmed by such methods and be hindered in their learning processes [13], [14]. Scaffolding and principles from instructional design should thus be considered [15]. Due to the nature of AR as a combined representation of different media [16], [17], AR representations cannot be treated as a single medium. Learning with AR should therefore also consider the principles of multimedia learning [18].

These considerations have led us to develop a model for AR book design that combines the technical features of AR with instructional design principles. The result is the ARI^{2}VE model, which we would now like to present and discuss for the first time. An example of an AR book is presented that had been designed according to the components of the model.

II. The ARI^{2}VE model

With the ARI^{2}VE model, we try to combine the potentials of AR technologies suggested in the literature with findings from the science of learning and instruction. For us, AR is the computer-aided extension of reality, with interaction possibilities in real-time and the registration of virtual objects aligned with the objects of the real world [16], [17]. From the field of learning research, we integrate the considerations of effective, efficient and engaging instruction [19], [20], the components from the 3C model (content, communication, construction) [21] and the principles from the cognitive theory of multimedia learning (CTML) [18], [22]. The components of our model are described and discussed in detail below.

A. I: Interaction

The first *I* in our model stands for the interaction possibilities. These must be considered from the very beginning and can be realized in several ways, especially in AR-supported learning materials:

- Interaction with the AR objects: Here, the objects and visualizations represented by AR are in focus. Learners

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can zoom in, zoom out, rotate, and model them to create new objects and get immediate feedback on the changes made.

- Interaction can also take the form of social interaction with other learners and with teachers. The AR books then are shared by several learners and the learning content is discussed and debated together.

B. I: Interplay

The second *I* represent interplay and describes how the different media variations offered in our AR books relate to each other, i.e. texts, pictures and tasks do not stand alone but are supplemental. The augmented object is also included here and contextualized in the examination of the text. These considerations are based primarily on the multiple representation principle [23], [24]. According to this principle, external representations have different functions, such as the addition of tasks to the learning content and/or a supporting function in building a deeper understanding, e.g. when AR objects illustrate relations or concretize abstract concepts. The complement role of interaction and AR-visualizations in AR books to contribute the overall understanding of the content is also recommended in [4].

C. V: Visualization

AR stands like no other technology for being able to make the invisible visible and to make abstract processes easier to understand through stimulating representations [25], [26]. Due to the very definition of AR, we cannot understand AR as a single medium. Instead, AR systems enable the integrated, i.e. temporally and spatially parallel, representation of different presentation formats [27]. Audios, videos, animations, 3D objects, even simulations could be components of AR elements [28]. If different forms of media are presented together, we speak of multimedia learning. For this reason, learning with AR should be based on the principles of the cognitive theory of multimedia learning (CTML) [18], [29] in order to support learners during the examination of visualizations and not to overload the capacities of their working memory [14].

Furthermore, it is essential to consider with which focus the AR visualization was implemented and whether its reputation is essential for the learning process [30]. The focus can be the extension of the real object or image that is actually at the center of the learning process, as in the case of the extension of an image during a museum visit with information about the artist. Alternatively, the central message of the AR visualization is found in the AR object itself. If the AR visualization is essential for learning progress, it promotes the achievement of the desired learning goals. However, AR can also be used as an "additum" to address personal preferences and interests and to facilitate personal learning paths [30].

D. E: Engagement

Tasks realize the engaging of the students during the use of our AR books. These can be found on every double-page and vary concerning the learning activities necessary to solve them. Tasks are central to each learning environment [19], [21] and involve different activities, e.g. summarizing, drawing, creating mind-maps; they ensure that the information presented is actively processed by the learners and integrated into their prior knowledge [31]. They also serve as a self-regulated check of the learning progress and indicate the learners whether they can apply the newly acquired knowledge [21]. The tasks, in turn, should interact with the texts, images and AR visualizations and can be completed by the learners in various ways. In our books, we have designed the tasks in such a way that the students can draw and/or write directly into the book with a pencil. The tasks can also be offered and worked on directly via AR, like shown in [10]. Materials outside of the book can also be used as a basis for the tasks. For example, it would be quite conceivable that learners collaboratively solve a task on a poster or whiteboard app on a tablet computer and then present it to their fellow learners [32], [33]. Here, teachers should decide how and where the solutions to the tasks should be recorded, based primarily on the learning objectives.

Figure 1 provides an overview of the components of the ARI^{2}VE model.

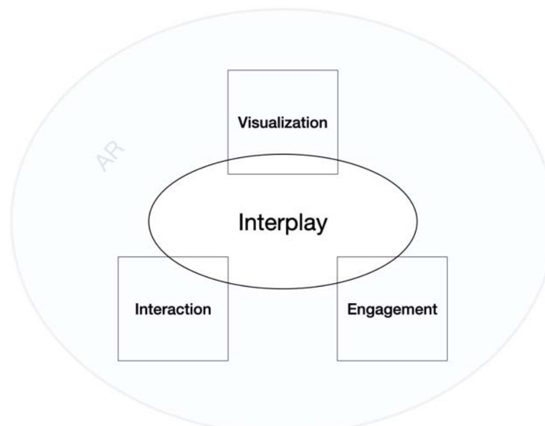

Fig. 1. Overview of the components of the ARI^{2}VE model.

III. Application of the ARI^{2}VE Model

Currently there are three books on different topics, which are designed according to the principles of the model [34]. One booklet covers physics with a special focus on light and water, another one with traffic education and another one invites the learners to an interactive journey to ancient Egypt. A total of about 2.000 of these thematic booklets are already in circulation in the German-speaking countries. The booklets are being tested in practice in 23 partner schools from primary school to the upper secondary school. The evaluation is carried out in the context of student theses, first results are expected in autumn 2020.

Here, we would like to present an example of a double page spread from the theme booklet on the interactive journey to ancient Egypt (Fig. 2). This is used to visualize the components of the ARI^{2}VE model.

As shown in Figure 2, the left side contains textual information (1). The trigger image is located on the upper right (2) and the corresponding task (3) for engagement below. To complete the task, the learners study the text and the visualization (interplay). The visualization is shown in Figure 3.

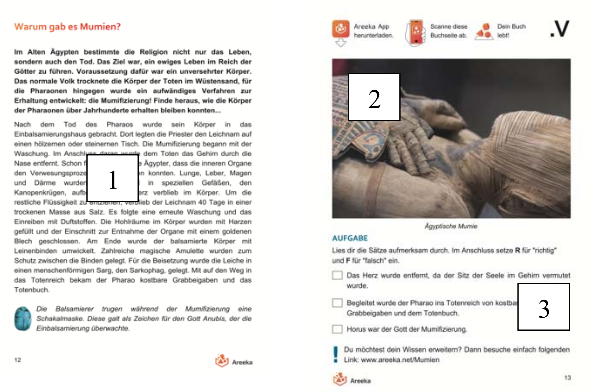

Fig. 2. Example of a double page of the history booklet (in German).

In this case, the trigger image in AR reveals a simulation of mummification. The learners can not only view the scene from all sides, but also interact with the tools and canopies (interaction, here: directly with the AR element).

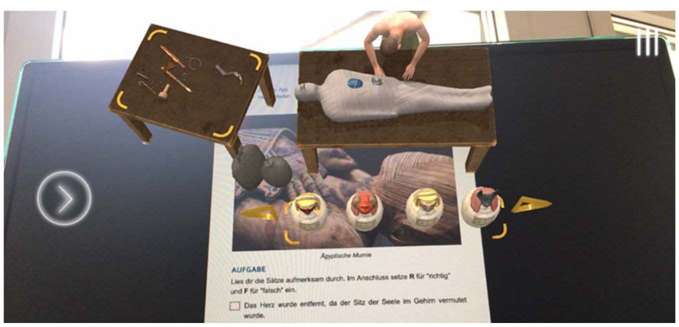

Fig. 3. AR visualization of mummification, here as a simulation.

IV. DISCUSSION

In this article, we presented the components of the ARI^{2}VE model as we used them for our AR books. We used the *first principles of instruction* [19], [20] as well as the components of the 3C model content, communication and construction [21] as a basis. Since learning with AR is to be understood as multimedia learning, we also integrated the principles from the Cognitive Theory of Multimedia Learning [22].

AR as a particular technology by itself will not lead to better or different learning, so it is essential to plan the use of AR carefully and to implement it in line with the learning objectives [30], [35]. The increase of the motivation or the satisfaction of the learners as sole success factors will be too little if effective and efficient learning is to be initiated and above all, maintained. Surely not all components of our model have to be considered when designing AR books. Crucial for successful learning with AR are meaningful tasks that go beyond the mere observation of 3D objects [36]. Learners should be able to solve these tasks by dealing with content that does not overload them cognitively but supports them in their knowledge-building processes. AR representations can be of lasting importance here, if the AR content is aligned with a learning goal. For example, positive results were found in the STEM area and also for the training of special skills such as spatial awareness [37], [38].

The ARI^{2}VE model was presented for the first time in this paper, here, especially for AR books. Since the model is based on previous findings from the science of instruction and learning, the components could also be useful for other forms of AR-supported learning. For this, however, empirical studies are necessary to be able to make serious statements.

This is our mission in the near future. We want and will empirically examine the ARI^{2}VE model and critically examine its components. This also requires international cooperation and exchange, which we would be pleased to see.

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