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Evaluating Digital Instructional Materials Using Eye-Tracking: A Pilot Study Across Multiple Learning Modes

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Abstract: This study developed different types of digital interactive teaching materials, including click-based e-books, game-based learning materials, and tabletop virtual reality materials. The goal was to assess their effectiveness through learners' eye-tracking data to understand the potential challenges and benefits these materials offer. The study involved 12 students performing eye-tracking tasks to collect implicit eye movement data. The eye-tracking analysis revealed that most learners focused on visual and pictorial content. While VR environments helped learners immerse themselves in the scene, the study suggests that 3D-based learning materials require careful design regarding area separation, as learners tend to focus heavily on the central visual field.
Keywords: Interactive learning materials, Eye-tracking, Learning material design

1. Introduction

With the continuous advancement of digital learning approaches, instructional materials have diversified substantially, incorporating formats such as videos, e-books, interactive game-based resources, and virtual reality applications. Each format offers distinct affordances and instructional features (Lee, 2017; Li et al., 2019). The design of digital instructional materials should not only integrate sound instructional design principles and learning strategies to create an appropriate learning environment, but also carefully consider media selection and interaction design, as these elements directly shape how learning content is delivered and experienced by learners.

In parallel, eye-tracking devices analyze learners' eye movements to reveal their visual reading paths and cognitive processing when engaging with learning materials (Chen et al., 2010). The use of eye-tracking tools provides valuable internal data on learners' cognitive processing, complementing traditional external assessments such as questionnaires and tests. Accordingly, this study aims to develop three types of digital instructional materials including click-based e-books, game-based interactive materials, and tabletop virtual reality covering the same topic of campus environment and norms, and to examine the learning effects of these three interactive instructional formats through eye-tracking data.

2. Literature review

Moreno and Mayer (2007) identified five levels of interactivity, ranging from dialoguing to navigating. This study integrates these concepts into the design of three specific material types. E-books combine digital content with interactive features, enhancing learner participation through convenient access and multimedia presentation. Studies indicate that e-books can improve learning ability and engagement compared to traditional text (Lin, Huang, & Chen, 2018). Game-based learning involves goal-oriented activities that stimulate intrinsic motivation and provide immediate feedback. Effective game design must consider interface

usability and storytelling to foster higher-order thinking (Wu et al., 2012). 3D games can offer immersive experiences, though 2D interfaces remain common. Virtual Reality (VR) creates 3D spaces offering immersion and interaction (Berkman, et al., 2020). While 3D presentations can stimulate behavioral activation, research results are mixed; some studies suggest that while presence is higher in VR, learning outcomes may not necessarily surpass those of 2D environments, and issues like disorientation can occur (Berkman, et al., 2020; Buttussi & Chittaro, 2018). Eye-tracking devices record gaze trajectories, heatmaps, and Areas of Interest (AOI) to analyze cognitive processing. These metrics help researchers understand which parts of the instructional material attract attention and how interface design influences the learning path (Chen et al., 2010).

3. Methodology

The purpose of this study was to examine the learning effects of different types of digital instructional materials through eye-tracking data analysis. The learning materials focused on "Campus Environment and Norms" and were divided into three units: administrative locations, facility usage, and student activities. Three types of instructional materials were developed. The e-book presented content in a two-dimensional format with page-flipping controls and animations, allowing learners to navigate linearly or non-linearly using a mouse. The game-based material adopted a two-dimensional role-playing format in which learners completed tasks using a keyboard and mouse, and included a map, scoring system, and task list. The virtual reality material was presented as a desktop-based VR experience featuring three-dimensional campus buildings, enabling learners to explore the environment from a first-person perspective using a keyboard and mouse.

A total of twelve first-year university students from a single university participated in the study and completed eye-tracking tasks to collect implicit eye movement data. Participants were randomly assigned to one of the three instructional materials, with four students in each group. Each participant interacted with only one type of material and completed two tasks designed to examine the effects of different operational or presentation methods while maintaining consistent instructional content across materials. The two tasks targeted different learning objectives: (1) locating target buildings to assess navigation and visual search, (2) learning the procedure for applying for a student loan to evaluate information retrieval and procedural learning.

Eye-tracking data were collected using a Tobii Pro Nano eye tracker, with gaze point positions recorded and analyzed through iMotions software. Prior to the experiment, a nine-point eye-gaze calibration procedure was conducted using Tracker Manager to ensure accurate data collection, during which participants followed a sequence of points displayed on the screen. After calibration, eye movement data were recorded and visualized to analyze learners' gaze behaviors across different tasks and instructional materials.

4. Pilot results

The learners completed two individual tasks using one of the three instructional material types (e-book, game-based, or VR-based). Task 1 examined learners' learning processes when identical instructional content was presented in different modalities. Eye-tracking data, including gaze paths and heatmaps, were collected, followed by a short assessment and brief interviews. The heatmap results indicated that learners in all three conditions attended to the learning content. In the e-book condition, learners primarily focused on textual and graphical information and then followed the instructions to locate target buildings. In the game-based condition, learners' gaze paths closely followed the avatar as they navigated to the target location. In the VR condition, learners' attention was concentrated on the central region of the 3D environment, particularly on the avatar's face, suggesting that personified avatars effectively attracted attention. Interview feedback revealed that learners in the e-book and

game-based conditions experienced difficulties in understanding physical locations due to the 2D representation, whereas learners in the VR condition reported a stronger sense of presence and spatial understanding.

Task 2 explored the impact of different learning modalities and presentation modes on procedural learning outcomes related to applying for a student loan. Eye-tracking path maps and heatmaps were used to examine whether learners followed the reading sequence. The results showed that learners in the e-book and game-based conditions focused mainly on textual information, while learners in the VR condition attended to both central 3D objects and embedded textual cues. The findings suggest that interactive and spatial exploration features in game-based and VR materials may enhance information acquisition and procedural understanding compared to linear page-based e-book materials.

5. Discussion and Conclusions

The study developed three types of interactive materials and evaluated them using practical and empirical methods. The findings of eye-tracking data highlighted an important design insight: in 3D VR environments, learners' visual attention is predominantly fixed on the central field of view. This suggests that future VR instructional design should optimize the placement of key information within this central area or use better cues to guide peripheral attention. In conclusion, e-books are effective for straightforward content delivery; games excel in motivation; and VR is superior for spatial simulation but requires intuitive control design to reduce frustration. Future work should involve larger sample sizes for eye-tracking and explore these effects across different age groups.

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