Autobiographically Designing Mixed Reality for Lecturers

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Abstract: The implementation of educational artefacts based on new technologies depends on the skills and motivation of lecturers in the field. Aside from early adopters, lecturers often rely on best practices and exemplifications for their specific subject of teaching. In this work, we present how we applied end-user programming tools for Mixed Reality and the area of technical drawing, construction, and Computer Aided Design. With this approach, we created MACARONI, a **M**ixed Re**a**lity te**c**hnic**a**l d**r**awing secti**on** v**i**ew tool. In an expert user study, we collected insights on how lecturers at our institution perceive Mixed Reality as teaching tool, exemplified by MACARONI. Also based on the evaluation of our solution by the participating lecturers, we reflect on autobiographical design for the purpose of tapping in technologies for others. We argue that it helps to showcase the technology and how it can be applied for those lecturers, who did not consider using the technology before.

1 INTRODUCTION

Mixed Reality (MR)[1] has been used for teaching in various disciplines, for example in engineering (Orsolits et al., 2022), archaeology (Lohfink et al., 2022) and architecture (Darwish et al., 2023). In a literature review Ashtari et al. (2020) identified that the threshold to design and develop respective educational artefacts still is high. Also, they state that the development and design process of such applications often remains fuzzy as insights on the use of current VR and MR authoring tools are missing. In addition, to the best of our knowledge, designing or choosing educational artefacts for higher education usually remains with the lecturers. This is confirmed by experts in the area of VR *and* MR (XR) stating that funding, lack of expertise to select suitable tools, and time, which lecturers have to invest, inhibit using XR in higher education (Probst and Orsolits, 2023), which can lead to some lecturers refusing to adapt new technology.

The creation or selection of educational artefacts, as well as integrate them within their lecture concept, is just one of many tasks lecturers have to address during their every work day. Most lecturers therefore can be considered to be end-user developers (see e.g., (Ko et al., 2011)) who learn the skills necessary to address a problem during the very process of problem-solving.

In this work, we present MACARONI, a **M**ixed Re**a**lity te**c**hnic**a**l d**r**awing secti**on** v**i**ew tool, which has been developed to exemplify MR for teaching technical drawing, construction and CAD. Lecturers were invited to participate in an expert user study, to give feedback on the design and its potential use. The study also allows us to collect insights on how MR teaching may look like in the selected application area of technical drawing, construction and Computer Aided Design (CAD).

This work is structured as follows: We provide theoretical background, followed by the presentation of the educational artefact MACARONI. Next we introduce the design of our expert study and the approach to analyse the collected data. Finally, we present insights in the results of the study, followed by a discussion.

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[1] We understand Mixed Reality as it was defined by Milgram and Kishino (1994), including only Augmented Reality and Augmented Virtuality.

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2 BACKGROUND

Employing MR for CAD education and related subjects has been successfully exercised by scholars: Kraus et al. (2022) present their design flow of creating MR applications for teaching structural design. In their user study, they could identify that even though XR is yet not established as teaching material, their user group (civil engineering students) reported significant potential for teaching structural design. According to the authors, XR as teaching material has not received enough attention by the research community and therefore see potential in improving didactics and learning-success orientation.

Serdar (2016) motivates the use of MR for improving students skills to visualise objects in technical problems. Even though, engineering drawing courses can be employed to help students extending their skill set in that regard, lecture time usually is limited. A user study with students could show that MR may support students further for this task. Also for assembly drawings, Laviola et al. (2022) propose an MR application which overlays a printed technical drawing with the final assembly. They conducted a usability evaluation and plan to evaluate learning effects in future work.

Technology exploration and design initially is guided by the first-person experience of the designing person(s) (in this work, the MR creators). During early stages, these persons have to understand the opportunities and limits, the selected materials come with, find ways to address basic and advanced problems and may need to acquire further materials as well. This is especially challenging in the case of end-user developing, which lecturers often are confronted with. End-user developers often need to make ad-hoc decisions to be able to continue, for example by choosing a development tool (Ashtari et al., 2020). Current advances in MR authoring and design tools already made it easier for a layperson to start creating their own MR solution (e.g., (Puggioni et al., 2020)), but these tools still have limits or require acquiring expert knowledge from various areas. Lecturers find themselves in a tension between achieving their imagined design solution and the limited time available for skill acquisition and implementation. Also, Amhag et al. (2019) report that lecturers need to be able to anticipate the pedagogical value which lies in digital educational artefacts to be motivated to start working with them.

It is unavoidable that the word "reality"[2] influences the expectations from new users. We observed students first learning about XR, describing the technology as enabling an experience that is "like the real thing" and "being there". However, it is not straight forward to define what users will perceive as "real". The literature seems to centre around a concept that the experience with computer-generated imaging meets the users' expectations of "what reality is" (Goncalves et al., 2021). Scholars discussed factors such as conforming to users' expectations, and adequate, non-lagging viewpoint changes (Sutcliffe and Gault, 2004), and including virtual objects, sounds, and scenes as part of what a user will consider when judging the level of "realism". Some work argues that perceived "realism" depends on the physiological state of the user and not on the application's graphics quality (Lipp et al., 2023; Molina et al., 2020; Yu et al., 2012).

[2]To acknowledge the fact that what humans perceive as "real" is highly individual, we refer to "realism" and related termini in quotes.

3 METHOD AND SETUP

3.1 MACARONI

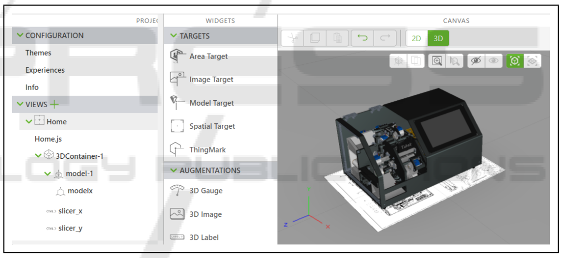
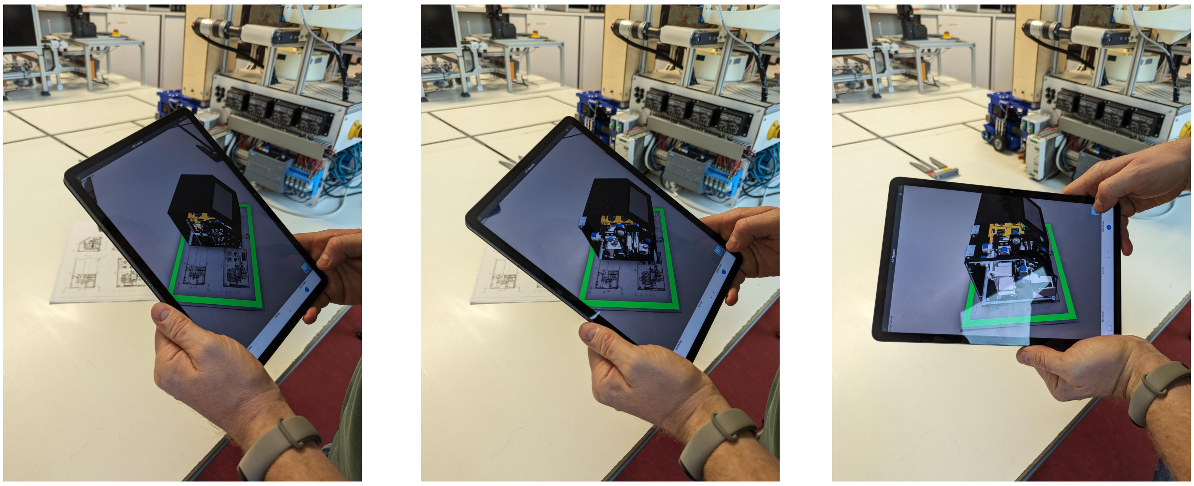


Figure 1: What-You-See-Is-What-You-Get (WYSIWYG)-editor Vuforia Studio, used during the design of MACARONI. Shown is the final design of the 3D content: The assembly (MR-content) is placed above an imaged-based marker, later printed on paper to augment it with the assembly.

For the presented study, a **M**ixed Re**a**lity te**c**hnic**a**l d**r**awing secti**on** v**i**ew application (MACARONI) was developed and designed using a What-You-See-Is-What-You-Get (WYSIWYG)-editor[3] (see Figure 1). The goal was to exemplify creating MR educational artefacts for subjects in the area of industrial engineering.

The MACARONI-alpha (i.e. the foundation of MACARONI) was created as part of a bachelors' thesis in the field of mechatronics and robotics under the supervision of the first author. The student had extended learning experience in the area of technical drawing, construction and CAD, since these sub-

[3]PTC Vuforia Studio



(a) 0° (b) -45° (c) -90°

Figure 2: Moving the section pane by tilting (rolling) the tablet PC. The further the tablet PC is moved from the 0° position (portrait mode), the further the section pane is moved to the left. Therefore, in the -90° position, there is no section through the assembly.

jects are taught and applied in this field of study in all semesters previous to the bachelors' thesis. Reflecting on this experience to inform the design and development of the application was part of the task, and the student was encouraged to consider their own experience whenever a design decision was to be motivated. In a time span of about four months, the student explored the possibilities and limits of the WYSIWYG-editor within the task of creating an MR section view application with spatial interaction. The results were exemplified in the MACARONI-alpha. To extend spatial interaction in smartphone-based MR from changing the perspective on the displayed content (by moving the smartphone around the scene) to moving a section plane through the model by rotating the smartphone was introduced as shown in Figure 2.

The first author refined the MACARONI-alpha by cleaning up the interface and user flow. The resulting MR-content, MACARONI (see Figure 3), allows users to explore a 3D Object by moving the smartphone through the environment.

MACARONI can be accessed by using a content viewer app of the used framework[4], which is available for common mobile operating systems. It generally is intended to serve two purposes: First, it exemplifies what current WYSIWYG-editors for smartphone-MR are capable of. We wanted to demonstrate the capabilities of such editors to give lecturers insights to what they can achieve with software which allows to predominantly work with graphical programming (by dragging and dropping items to add and logically connect them). Second, it introduces an approach for spatial interaction by moving the section view via rotating the device accordingly. This shall provide a more tangible mode of interaction compared to input elements on the touchscreen, such as sliders or arrow buttons. Also, we saw it as a preview on the capabilities of smartphone-based MR in general.

3.2 Expert User Study

In order to understand the personal stance of lecturers, we conducted an expert user study which consisted of a familiarisation with the app MACARONI, followed by expert interviews.

3.2.1 Participants

Five lecturers (one female and four male participants) at our institution who have experience in teaching technical drawing, construction, and/or CAD participated in the study. One assigned themselves to the age group of 18-30, three to the age group of 31-40, and one to the age group of 41-50.

3.2.2 Procedure

The overall duration of the study on average was 30 minutes per participating lecturer. The participating lecturers received an explanation of the study and provided consent. The participating lecturer's identification was anonymised. Participating lecturers were asked to fill a pre-questionnaire collecting basic demographic data, self-declared experience with XR as well as the years of teaching in the field. This was followed by an exploration task. Once the task was com-

[4] Vuforia View

pleted, a semi-structured interview was carried out.

3.2.3 Exploration Task

The study coordinator asked the participating lecturer to scan a printed QR-code code with the content viewer app, which was opened on a tablet PC (Samsung Galaxy Tab 7). The participating lecturers were asked to turn around the paper to find a technical drawing of an assembly and to point the camera at it. This initiated the displaying of the MACARONI content. The study coordinator asked the participating lecturers to explore MACARONI until they felt like they understood the features of all four 2D interaction elements (see Figure 3) and mentioned that rotating the tablet PC should be considered. The participating lecturers were encouraged to use thinking aloud, to explain what they are doing, but also add further thoughts on MACARONI while using it. They were informed that questions in general will not be answered during the exploration, but that the study coordinator will help if they express any problems to keep the exploration running. The study coordinator was equipped with a form to structure the observation of the participating lecturer. On this form, the duration of the exploration was noted, but also there were bullet points for noting observational data, and whether and why the study coordinator had to support the participating lecturer. Furthermore, there was a dedicated space for adding other observations. If the participating lecturers had agreed to, screen and audio recording was activated on the tablet PC during the exploration to collect further insights. When the participating lecturers were satisfied with exploring the app, they handed back the tablet PC and the screen recording was saved.

Figure 3: The final design of MACARONI (screenshot from the WYSIWYG-editors preview). Toggle (1) changes the direction of the section, dropdown box (2) allows selecting the axis on which the section plane is moved, the checkbox (3) enables the section view. If section view is enabled, the floating button (4) is displayed which fixes the section plane at the current position, so the user can inspect the current section without accidentally changing the section plane's position.

The app exploration was followed by a semi-structured interview to collect knowledge about how the current technical drawing, construction, and CAD lectures are structured. We also wanted to understand if and how MACARONI could be used in the lectures, the potential for improvement of MACARONI and any further discussion topics. During the interview, MACARONI was shut off, but the technical drawing was still in front of the participating lecturers. The interview was audio recorded, if agreed to, and closed with a debriefing.

After the participating lecturer was dismissed, the study coordinator reflected on the session and took additional notes.

3.3 Data Processing and Evaluation Approach

Both, the screen and audio recording from the exploration and the voice recording of the interviews, were transcribed using an offline speech recognition model[5] and dedicated transcription software[6]. The resulting files (*.srt) were edited[7] to fix errors in the automatic transcription. This set of tools allowed us to transcribe and edit completely offline to protect the personal data of the participating lecturers.

The resulting transcripts are optimised by the speech recognition model automatically, hence elements specific to spoken language (as opposed to written language), such as filling words (e.g., “um”), stuttering or hesitation, are not fully represented in the data. We decided that these are not necessary in the interview transcripts for our analysis for two reasons: On the one hand, in the interviews, the study coordinator guided the interviews and would have noted conspicuous hesitations in the interview reflection. On the other hand, the interviews were held in German, and for the purpose of presenting

[5] OpenAI Whisper
[6] Buzz
[7] Subtitle Edit

the data were translated into English. Since, based on our experience, elements specific to spoken language appear to differ in-between languages and often can not be matched without changing semantics, we excluded them from the transcripts. In contrast, the screen recordings of the app use were annotated with information on the user behaviour, which could be observed in the video but also from the recorded audio and therefore may also reflect elements specific to spoken language when it appeared to be adding to the data corpus. We decided for manually re-adding these annotations, because their exploration could also deliver insights on how lecturers comprehend MR in action.

We employed reflexive thematic analysis following a deductive approach (Braun and Clarke, 2006). In order to identify the circumstances the participating lecturers are in when teaching and the potential they see in using MR for teaching technical drawing, construction, and CAD, but also the related challenges, we examined the data according to the following themes:

Teaching Style. How are the related lectures structured and what theoretical body is guiding it?

Expectations on Mixed Reality and App. What do participating lecturers expect from smartphone-based MR?

Stance on Mixed Reality. What do the participating lecturers in general think about MR as a concept for providing educational artefacts?

4 RESULTS OF THE EXPERT USER STUDY

The participating lecturers rated their experience in XR (referred to as VR/MR/AR) ranging from "no experience" (2) over "already tested" (2) to "occasional use" (1). None stated that they used it "often" or "regularly". One participating lecturer described this experience to be in the area of "rating construction and design in VR". The other two participating lecturers explained that they had played games in XR, one of which used a Google cardboard[8]. One reported that they had experienced symptoms of simulation sickness (dizziness) while playing in VR.

In the following, participating lecturers are referred to by using PL and their random ID (e.g., PL71).

[8]A cardboard based do-it-yourself kit which can hold a smartphone to use VR apps.

4.1 Teaching Style

Domain-specific culture influences the educator's teaching style, for example by associating visualizations to known software ("Definitely looks like SolidWorks.", PL36). Some participating lecturers emphasised the need to see things with the lenses of an engineer: "what is interesting for me in technical drawing is the link between what I see there and how it is presented here" (PL36).

According to the participating lecturers, the subjects of interest are taught early in the study programmes (up to the third semester). However, an important driver in students' progress is own initiative: Students are given homework and are asked to prepare themselves by watching instructional videos on the use of CAD software, usually on material created by the software manufacturer. Normally the software is selected by the head of the programme. The learning process consists on starting with 2D drawing and increase the complexity, integrating 3D Objects. There was one participating lecturer who only used 2D views (PL71). All participating lecturers confirm that some students struggle with spatial cognition.

4.2 Expectations on Mixed Reality and the App

When observing the participating lecturers while exploring MACARONI, we noticed they seem to transfer the interaction concepts from their everyday smartphone use to MR. For example, all participating lecturers tried touch gestures (e.g., pinch to zoom or swiping) or direct interaction with the 3D object by clicking on it on the touch-screen or asking if it is possible to directly interact. Four participating lecturers required help from the study coordinator for understanding how to rotate the device in order to move the section view through the 3D model (PL36, PL71, PL214, Pl681). During every app exploration phase, the study coordinator had to hint that not just the device can be moved to change perspective on the depicted assembly, but also the technical drawing the assembly is projected to can be rotated for this purpose.

The participating lecturers predominately interacted naturally with the 2D interaction modes provided, specially in the beginning of the exploration. The used application only contains few 2D interaction modes, which are overlaid over the MR viewport and employ heavily used interaction elements on 2D interfaces. Namely, there is one checkbox, one drop-down box and one toggle. In addition, there is a play/pause button floating over the viewport (see Figure 3. Even though the way these interaction modes work was clear to the participating lecturers, there were varied reactions, with a participating lecturer stating “do not find the control system entirely plausible” (PL214). One participating lecturer requested an “undo-button” to reset the application (PL473). This was left out by design, since there is no intended initial state of the section. In general, all participating lecturers agree that MACARONI adds to the portfolio of educational artefacts, but does not replace another educational artefact entirely.

4.3 Stance on Mixed Reality

Participating lecturers agree that one advantage of MR in the context of technical drawing, construction, and CAD is that students can explore 3D objects in the students’ three-dimensional (Euclidean) environment and interact with it.

Engagement and some presence-like phenomena by in-action-expressions of joy of use or other positive feedback during use have been indicated by the participating lecturers, e.g., “I think it’s cool. That’s nice” (PL473), after concluding that they must have seen all features of MACARONI. We also noted, that one participating lecturer (PL214) was briefly experiencing some tracking issues, which left them “unimpressed” (wording from observational data by the study coordinator). They just continued after the tracking has settled again.

Some participating lecturers already plan improving the spatial cognition with other educational artefacts, namely 3D printed objects (PL214) and XR (PL36). Along with the list of improvements collected from all five participating lecturers this indicates that the participating lecturers see potential in MR and understand its capabilities to the extent that they can think beyond the given example by MACARONI.

5 DISCUSSION

CAD tools are among the toolbox available for technical drawing, design and construction. The capability is there to generate advanced visualizations of products or buildings before anything has been physically created or built. Students learn technical drawing starting with free-hand and 2D drawing and progressing in CAD from 2D to 3D objects and 3D object editing and manipulation. Our lecturers have identified several challenges to achieve their learning goals related to spatial cognition. The students can struggle to extract information from 2D to create a 3D object. It could be argued that digital experiences in day-to-day life had a minor component of 3D spatial navigation, and therefore appears to had little impact on acquiring the specialized learning required for CAD work.

The MR app MACARONI presented in this paper runs in a tablet PC. It was interesting to see the participating lecturers transferring behaviours from their use of smartphones to the interaction with the app. They appear to find some manipulation operations not intuitive enough, which should be taken into account for future improvements. The focus on using 2D interaction modes by the participating lecturers could be due to a sense of familiarity but also highlights a shortcoming for the app. This focus may also have let to missing an “undo” option, since it is common practice in application design to include a possibility to revert to previous states. It might be something to re-consider if the app is to be comparable with CAD use. Finally, adding an onboarding sequence to the app, explaining how to control it, might help further understanding both, the 2D interaction and the 3D interaction, MACARONI offers.

MR, despite not being a new technology any more, is still relatively unexplored by many lecturers (see also (Ashtari et al., 2020)). This might be a reason behind the struggle by some participating lecturers with the app. Nonetheless, there were comments about ”realism”. It might be that it being an MR application, it creates some expectation in the users on the level of “realism”. We did not perceive the comments to be entirely critical but more a consideration of possibilities, for example known from high level rendering and powerful graphic cards which can support photorealism and high-fidelity visualizations, and their impact on the user experience, both positive and negative. The participating lecturers praised the user experience of the MR application, though.

The participating lecturers see a role for the app in complementing their lectures. Handing out the MR application, as proposed by Serdar (2016), might help to improve 3D imagination, which the participating lecturers noted to be one of the major problems to be addressed during the lectures. Based on the reported homework, an application such as MACARONI may allow lecturers to focus more on other topics, which was mentioned by participating lecturers during the interview. An interesting outcome of the interviews was finding that there were lecturers already considering XR for addressing learning aspects.

We applied an autobiographical design approach (see e.g., (Cochrane et al., 2022; Neustaedter and Sengers, 2012)) in two iterations, each taken out by one of two different MR creators (the bachelor student and the first author). This approach turned out to work well for introducing lecturers who did not make up their mind on MR educational artefacts, yet. Therefore, it serves well to introduce colleagues to a new technology supporting them in their teaching, by exemplifying MR in application.

We believe that gathering opinion from experts was useful to understand the overlap of our own perception of MR as an educational tool with a broader perception of the target group of lecturers of the selected subjects. This also provided feedback on how to improve MACARONI. The selected, solely qualitative approach provided extensive insights into how designing and developing educational artefacts and how using them in the lectures my unfold at our institution. Conclusions drawn on the applicability of MACARONI are certainly difficult to be generalised or transferred to other institutions or different teaching contexts. Certainly, an argument would be to try the app with lecturers in similar positions in other institutions, but it is beyond the scope of our current funding.

We consider the presented themes to be subject to work, to draw a clearer picture of how the MR design space is shaped by facilitating lecturers in the practice. We invite scholars to extend these themes and/or assign further sub-themes based on their experience.

6 CONCLUSION

Designing computer supported educational artefacts for lecturers comes with several challenges: the communication between different domains (MR experts and experts in the subject field), the personal teaching style, the individual appreciation of the underlying technology of the solution, and the perceived need to change lecturing approaches. These and other factors need to be carefully mitigated by the educational artefact creation team. Since we created MR content for others, they are to decide how and when to use our application, and therefore need to be included in the design process to channel the outcome.

In order to understand how lecturers at our institution, in their role as facilitators for new computer supported educational artefacts, might apply predesigned educational artefacts, we provided MACARONI, an MR application for displaying sections in CAD assemblies and evaluated the resulting design with five lecturers, teaching technical drawing, construction, and/or CAD at our institution. We could identify that for new technology, with little to no expectations and experience by the lecturers, this approach can help to introduce MR to the field. We also learned that for lecturers who already had the chance to consider MR for their teaching, there might be the risk, that concrete ideas are not met by the implementation of the predesigned educational artefact. Still, the MR application overall was received well by the experts participating in the study. We also could employ it as a discussion starter on teaching technical drawing, construction, and/or CAD and how MR can be supportive in this task.

We hope to encourage other researchers with this paper to further investigate and extend the presented themes. Future work will aim at addressing some of the improvement recommendations in usability and navigation and carry out a wider evaluation with students, in order to understand how our design unfolds in the practice of teaching, and specific learning experiences. Ideally, we would like to evaluate the app with lecturers in other institutions (teaching technical drawing, construction, and/or CAD) to obtain a broader evaluation, allowing for generalising results beyond the context of our institution.

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