UNIVERSITÄT DUISBURG ESSEN

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Bachelor Thesis Application

Implementation of an interactive poster using Raspberry Pi and traditional crafting materials

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Contents

Chapter 1

Introduction

In academic and research settings, posters serve as a key medium for presenting work, fostering dialogue, and sparking collaboration. While effective in their simplicity, traditional paper posters often rely heavily on the physical presence of the researcher to guide discussions, answer questions, and provide context. This dependency limits their utility, particularly in contexts where accessibility, interactivity, or remote engagement are prioritized. The proposed thesis topic, "Implementation of an interactive poster using Raspberry Pi and traditional crafting materials," addresses this gap by exploring how modern technological tools can enhance the traditional research poster, transforming it into an interactive and self-explanatory artifact.

This project tries to bridge the fields of technology, design, and communication. By integrating microcontrollers such as Raspberry Pi with traditional crafting materials like paper and markers, the aim is to create a hybrid solution that maintains the familiarity of traditional posters while introducing elements of interactivity.

The thesis will adopt an iterative design-implementation-evaluation approach, ensuring that the final prototype meets the needs of its stakeholders and demonstrates usability in real-world scenarios. Initial phases will involve identifying the primary users and their requirements through stakeholder analysis. Based on this foundation, mockups and prototypes will be developed and refined through user feedback and usability evaluations. Each step will build toward delivering a functional and engaging interactive poster that leverages technology to improve the accessibility and communication of research.

This project aligns with the broader goal of advancing educational and presentation technologies by introducing creative, user-centered approaches to traditional formats. By focusing on the process of integrating hardware, software, and crafting techniques, this thesis will not only contribute to the field of interactive learning technologies but also inspire further exploration into how technology can enhance communication in academic and professional

contexts.

Chapter 2

Related Works

2.1 Background and Limitations of Traditional Posters

(Citation on what are posters, maybe Soon et al., 2022?: "Posters are displayed on boards or stands and viewed from a distance. Posters are displayed simultaneously over the course of the conference and attendees are free to browse and study at their own convenience" Or put this in the introduction?)

Traditional paper posters have long been used as a tool for conveying information, whether it be in educational, professional, or public settings Rowe and Ilic, 2011; Soon et al., 2022. "The 'traditional' poster presentation aims to present information in a succinct manner"Rowe and Ilic, 2009. However, despite their widespread use and popularity Rowe and Ilic, 2011, simple paper posters suffer from significant limitations, particularly in their ability to actively engage the audience and their bandwidth for transferring knowledge Ilic and Rowe, 2013. It was shown that while most event participants agreed that posters were a good medium for knowledge transfer Arslan et al., 2014; Goodhand et al., 2011, the knowledge retention of their viewers was often abysmal if they were read at all Goodhand et al., 2011. For example, at the Digestive Diseases Week (DDW) and British Society of Gastroenterology (BSG) meetings, only <1.5% and <0.3% read any of the posters respectively. "Delegates remembered very little when phoned about posters two weeks later" Goodhand et al., 2011. While it may be the case that "Publication rates of abstracts submitted to the BSG seem to be falling, implying that for more and more research, poster presentations are the only opportunity to share research findings" Goodhand et al., 2011. "Abstracts selected for presentation are usually collated as conference proceedings, but rarely found in the published literature." Soon et al., 2022.

These findings highlight a key challenge with traditional paper posters: their ability to captivate and engage an audience effectively **(citation needed)**. Given the limited time and attention that viewers devote to posters, their aesthetic appeal becomes a crucial factor in attracting viewers and encouraging interactionGoodhand et al., 2011. A visually striking design can often be the deciding factor in whether a poster is noticed, read, or remembered, emphasizing that aesthetics are not merely decorative but integral to the effectiveness of paper postersArslan et al., 2014; Erren and Bourne, 2007; Mabrouk and Schelble, 2018. "Studies that reported on the effectiveness of the poster presentation as a standalone intervention were unanimous in their conclusions that the poster was not effective at facilitating knowledge transfer be it through an increase in knowledge, change in attitude or behavior. his conclusion was supported by an evaluation study, in which participants identified that posters needed to be accompanied by another source of information to be effective – otherwise the only drawing point to the poster is the imagery." Ilic and Rowe, 2013 Factors like layout, format, readability, and even color schemes all influence how effectively key information can be conveyed to the reader Erren and Bourne, 2007; Ilic and Rowe, 2013.

"Given its passive nature; if not accompanied by an active intervention (e.g. oral presentation, physical interaction), which can help with aural and verbal learning exchange, the 'traditional' poster may only reach a limited proportion of its intended audience ." Ilic and Rowe, 2013 This nature also makes them badly equipped to accommodate alternative learning styles.Rowe and Ilic, 2009

"By embedding knowledge in interactions that involve people, it is possible to achieve reciprocal dialogue, which is the most effective method of transferring tacit knowledge." Ilic and Rowe, 2013

2.2 Evolution Toward Interactive Posters

2.2.1 Paper Posters

These interactions don't need to be exclusively based on dialogue only; Posters that ask the viewer to interact with them in some way help to attract attention and might even instigate thoughtful debate among attendees Dale and Kline, 2017. When asked for participation, participants spent longer at the poster, as it required them to think about the given questions/topic more thoroughly and deal with it in more detail Dale and Kline, 2017; Mabrouk and Schelble, 2018. This increased engagement also causes participants to return to the poster more frequently, even if it is just to compare their results with those of their peers Dale and Kline, 2017; Mabrouk and Schelble, 2018. This not only helps the participants to obtain more knowledge about a given

topic but also the authors, as it identifies improved ways to communicate complex information Dale and Kline, 2017. However, it is important to note that "Simplicity is vital so that attendees are not waiting for directions"Dale and Kline, 2017, "one engaged viewer will attract others"Erren and Bourne, 2007.

2.2.2 Digital Posters

Digital posters, sometimes called E-Posters, are a form of digital media, used to present information, just like "traditional" posters **(citation needed)**. "Reported advantages of the digital format include lower production costs, ease of preparation and transport, dissemination to a larger audience, and large archival capabilities"Newsom et al., 2021. This also opens up the possibility of maneuvering the presented content in a 3D space as well as embedding multimedia elements, creating new ways of presenting information to an audience Venkatesan and Coskun, 2019. Technologies like DIPP (digital interactive poster presentation)de Simone et al., 2001, MediaPosterRowe, 2009, as well as ePoster, emerged, trying to make use of the flexibility digital media has to offer **(citation needed or reformulate)**.

- DIPP (digital interactive poster presentation) "is a pdf version of a traditional poster that can be projected on a wall or screen at allotted times" D'Angelo et al., 2012, which is mostly used to briefly summarize the research, giving the audience the chance to decide which presentations to attend during the actual poster sessions D'Angelo et al., 2012.
- MediaPoster expands on this, adding the ability to embed external sources into an area of interest. Unlike normal hyperlinks, which would open a website or similar, a MediaPoster has a Media Display Area to the right, which would show the requested documents to the viewer, keeping them within the same environment with the poster always in full view. Rowe, 2009
- ePoster by Conventus takes a slightly different approach, offering posters in digital format on dedicated hardware. Presentations are held on specialized screens, controlled by a device similar to a smartphone. The control device mirrors the large display but enables manipulation of the viewing area, as well as selecting different presentations, with its touchscreen. **(What to do here????)**

(removed the pictures here, i probably need the rights to use them?)

This innovative approach to posters not only enhances the flexibility and interactivity of the presentation but also significantly improves the audience's

ability to grasp and retain the material **(citation needed or reform)**. The integration of multimedia elements such as pictures and videos captures attention more effectively than traditional posters Sumantri et al., 2024, serving as powerful tools for explaining complex concepts **(citation needed or reform)**. By embedding visual aids and interactive content, digital posters make the material more accessible and easier to understand, while also highlighting and clarifying essential parts of the presentationSumantri et al., 2024.

2.3 Technological Foundations for Enhanced Interactivity

2.3.1 Electric Circuits and Other Responsive Media

(redo this section? its mostly claims...)

Thanks to modern production and fabrication capabilities, building and integrating electric circuits has become more accessible. With the advent of tools like printed circuit boards (PCBs), conductive inks, and modular components, creating responsive and interactive systems is no longer limited to specialists. These advances have enabled the seamless integration of electric circuits into a variety of materials and media, opening the door to innovative applications in design, art, and engineering.

Among these innovations, responsive media such as Thermochromic ink, thin-film displays and a plethora of sensors have gained significant attention. Thermochromic inks, for example, can change color in response to temperature fluctuations, providing a visually dynamic way to convey information or interact with users. When paired with electric circuits, these materials create systems that are both functional and expressive, blending technology with creativity. Projects like PaperPixels Peiris and Nanayakkara, 2014 even go as far as to create Paper-based Displays with thermochromic ink by creating a circuit that powers piezoelectric elements according to an animation specified in their custom software, heating the ink at specific times. Due to the thermochromic ink's nature, they then change colors based on the temperature of the piezoelectric element. Depending on the "color scheme" chosen, images could appear "out of thin air" if the background color matches the unheated color of the ink.

Another notable project is IllumiPaper Klamka and Dachselt, 2017, which makes use of thin-film (TF) displays with electroluminescent or electrochromic properties, to light up predefined regions or change color based on user interactions. These displays are printed on the paper itself, creating

a seamless integration of digital and physical media. Users can then interact with the media via a pen, using the Anoto technology to track the pen's movement pattern and capture input. This works by printing an "invisible" dot pattern on the paper which encodes specific coordinates, allowing the pen to determine its exact position on the paper.

(Would love to put the picture here but i'd have to get the rights for that, right?)
(how to go about commercial solutions? hard to cite...)

Commercial solutions to this also exist, notably, Interactive Paper n.d. by a company with the same name, Interactive Paper. Their approach is electric circuits made out of conductive ink printed on the inside of the paper, sending NFC signals to a smartphone in contact with the respective NFC pad on the paper to then perform an action. They also offer a version that uses augmented reality to display content on a smartphone, though they have not published any information on the inner workings of this process.

2.4 Interactive Media in Education

(citation needed for below claims) Active student engagement is a cornerstone of effective learning environments. When students are actively involved in their educational experience—through participation, interaction, and hands-on activities—they are more likely to retain knowledge, develop critical thinking skills, and cultivate a genuine enthusiasm for learning. Engagement transforms the classroom from a passive setting into a dynamic space where curiosity and creativity thrive.

Research consistently highlights the benefits of interactive and participatory learning methods **(citation needed)**. Students who feel connected to their learning materials and peers are more likely to exhibit improved academic performanceGroccia, 2018. This is particularly true when teaching methods leverage modern technologies, real-world applications, and collaborative activities that resonate with students' interests and experiencesSahronih et al., 2019. "Even students who do not talk in class are often stimulated by questions or problem-solving exercises as they think about what they would answer in a particular situation"Yvonne Steinert, 1999, helping them become more actively involved with the material or content, teacher or even their peers Yvonne Steinert, 1999. Interactive media will be more effective when already associated with high learning motivation Sahronih et al., 2020, resulting in students, who are already highly motivated to learn and study the material, receiving an even higher beneficial effect from this form of media Sahronih et al., 2020. Students with lower learning motivation, how-

ever, could suffer from this kind of learning, as they might require more intervention and more supervision from a teacher during the learning process Sahronih et al., 2020. Thus, it is important to choose an appropriate kind of media.

Chapter 3

Methodology

(Generally, i'd leave all of this as is, put the implementation in the results section and discuss at the end in "Discussion" the limitations of this project and why things didn't go like i outlined here. Good idea?)

In this section, I will outline the iterative design-implementation-evaluation approach employed, to develop an interactive paper poster system using Raspberry Pi as the central microcontroller. The methodology is rooted in user-centered design principles, emphasizing collaboration with stakeholders, iterative refinement, and evidence-based evaluation to ensure the system meets its intended purposes.

The primary goal of this methodology is to create a system that integrates seamlessly with paper-based media while leveraging Raspberry Pi's versatility to control peripheral devices such as servos, LEDs, and screens. The system should balance technical functionality with usability, visual appeal, and ease of integration into various contexts, such as education, exhibitions, or public spaces.

My approach begins with identifying key stakeholders and eliciting requirements through interviews and contextual inquiries. These requirements guide the creation of initial design mockups, which visualize the interaction concepts and serve as a foundation for stakeholder feedback. Based on these designs, prototypes are developed incrementally, with each iteration refining the system's hardware, software, and user experience.

Each prototype undergoes systematic evaluation, combining qualitative and quantitative methods to assess its technical performance, usability, and alignment with stakeholder needs. The insights gained from these evaluations inform subsequent iterations, fostering continuous improvement and innovation.

By following this methodology, I aim to ensure the final system not only meets technical and aesthetic expectations but also achieves its intended

impact, creating a versatile, interactive platform that bridges the gap between traditional and digital media.

3.1 Identifying Stakeholders

In the development of this project, it is crucial to identify and engage the right stakeholders to ensure the system meets their diverse needs and expectations. Depending on who they are, the course of the entire project might change, thus this should be done as the very first step.

- End Users (General Audience): The primary users of the interactive paper poster will be individuals who engage with the poster in various environments, such as conferences or public exhibitions. These users could interact with the poster through buttons (capacitive or tactile) or sensors, triggering visual or mechanical responses (e.g. lighting, moving parts, screen display). Their experience with this system will be central to its success. As such, their feedback on usability, engagement, and overall experience is critical for shaping the design and functionality.
- Research group: On the other side of the poster presentations are the presenters themselves, the research group *colaps*. They will be the ones showcasing the poster and presenting their research using it. As such, not only does the system need to be reliable and easy to use, but it also needs to complement the content presented.

3.2 Eliciting Requirements

The process of eliciting requirements will be carried out to ensure that the interactive paper poster meets the needs of its primary stakeholders. This phase will involve gathering information about the expectations, preferences, technical constraints, and contextual constraints, that would shape the design and functionality of the poster. This could be done by interviewing the team of the research group to get a grasp on the factors mentioned, as well as collecting and surveying the necessary research material that is desired to be presented. When starting the prototyping process, designing mockups, and implementing various features, a strong feedback loop with the research group should be established to guarantee that no unnecessary features will be implemented or important features will be left out.

3.3 Prototyping and Evaluating

In the process of prototyping, mockups of the poster will be made, to test certain features and to obtain feedback on their implementation. This might

start with a random assortment of data (graphs, pictures, text, etc.) for a proof of concept but later evolve into prototypes using actual data from the research that is to be presented. Each prototype will then be evaluated according to the abovementioned fundamental requirements, the functionality of the feature(s) implemented, and the impressions and feedback of the research group.

(needs changing because we ended up going an entirely different direction than proposed here)

3.4 Potential Integrations

The actual list of features will be developed in cooperation with the group itself when surveying the research material, but the following can be set as the foundation:

- Technical reliability
- Portability
- Modular design
- Sturdy construction

In this short section, I'd like to outline some feature ideas I have for this project. This does not mean that all or even any of them will be implemented. Their usefulness, as stated before, strongly depends on the material that's supposed to be presented with this poster and the time constraints of this project. This is just to offer some ideas.

- Servos or small motors for moving parts, e.g.: A bar chart that "animates" its bars or changes their length depending on different contexts
- LEDs, e.g. to highlight certain elements or lead the viewer around the poster
- Speakers to offer audio playback
- 3D-printed parts for rigidity, robustness, and customization
- LCD Display(s), e.g. to show complex animations
- Buttons and capacitive touch sensors for user interaction
- Thermochromic ink: The idea behind PaperPixels fascinated me. Though it is highly likely, as that project in itself was made in the scope of a paper, that trying to implement similar technology will completely overload the scope of this project.

- Electric circuits: electric circuits could be embedded into the poster to create button-like features on the paper itself by completing a circuit with one's finger when touching an area. Similar to Interactive Paper.

As a Raspberry Pi only has limited GPIO available, additional microcontrollers like Raspberry Pi Pico or ESP32 could be used to modularize certain features and expand the IO capacity of the main controller.

3.5 Participants

The participants of this project consist of me and the team of the research group. Additionally, some colleagues with a background in education might be asked to provide feedback on certain design choices.

(Needs to be changed because there is no "paper" poster. Put the material research here?)

3.6 Materials

At the most fundamental level, a Raspberry Pi SBC or similar will be required for this project. For this, I propose using a Raspberry Pi 4 2GB. The reason for this is that, compared to the Pi 3 B+ for example, the Pi 4 offers two Micro HDMI and USB 3 ports, offering great expansion capabilities in terms of screens and IO. Its more powerful processor and ample RAM provide a more reliable basis for computing without the risk of running into any potential bottlenecks. Similarly, paper posters are required for the mockups and prototypes.

3.7 Procedures

To summarize the procedures outlined in the previous sections, first, the requirements of the poster and additional stakeholders will be identified. Secondly, a list of desired features will be compiled and evaluated. Following this, the prototyping process will start as outlined previously. Each prototype will then be evaluated periodically.

(I'd like to keep this in to then refer to in the results. Could be interesting to see how risks were actively handled once/after they occurred)

3.8 Risk Assessment Plan

The development of the interactive paper poster system may involve several risks that need to be identified and managed to ensure the project stays on track. The table below outlines the primary risks that can be identified at this point in time, as well as mitigation strategies.

Table 3.1: Risk Assessment Plan

Risk	Mitigation Strategy
Stakeholder Miscommunication	Establish clear communication channels (e.g., regular meetings, documented feedback) and maintain a feedback loop with stakeholders throughout the project.
Hardware Failures or Delays	Maintain spare components for critical hardware (e.g., Raspberry Pi, sensors, and peripherals) and plan for alternatives in case of supply chain issues.
Technical Integration Challenges	Adopt a modular design approach to minimize dependencies between components, allowing easier troubleshooting and replacement of individual parts.
Time Overruns Due to Feature Creep	Strictly prioritize features based on stakeholder requirements and time constraints; establish a clear Minimum Viable Product (MVP).
Insufficient Usability Feedback	Conduct frequent usability testing with diverse stakeholders at every iteration to ensure feedback is gathered systematically.
Software Bugs or System Instability	Implement version control (e.g., Git) and perform continuous integration and testing to catch and resolve bugs early.
Power or Portability Issues	Test power requirements early in the prototyping phase and optimize for efficient power consumption. Use battery packs or alternative power sources as backups.
Unfamiliarity with Certain Technologies	Allocate time for researching and experimenting with new technologies (e.g., advanced sensors or peripherals) during the early phases of the project. Seek guidance from experts if needed.

Chapter 4

Results

4.1 Eliciting Requirements

Here i would outline the interview we had when i compiled the list of questions.

4.2 Initial Proof-of-Concept

Outlining the initial design process, the thoughts that went into certain choices as well as our meeting where i presented this to you. Would include the design document with explanations.

4.3 CAD and Materials

Small section on the creation of the CAD model and material choices/tests

4.4 Early Prototyping

Even before our meeting, when the design i wanted to go for was finalized, i made a small 3d printed prototype to test the sensor and get a hardware proof-of-concept (i actually based the CAD design of the large poster on this one). I'd rather put this here for consistency. It'll probably be a small section but there are actually some problems i faced that i would like to outline here (particularly magnet orientation with the sensor). I later also tried to continue using this prototype before i got the hardware but it proved impossible to use the small SPI screen with the frontend framework i chose simply because i couldn't get the display driver to load correctly and had to write image as bytes manually to the display buffer. Could be interesting to mention too.

4.5 GUI Design and Creation

I made *some* Layout drawings for the tools and the application. While those were based on nothing but what i thought would make sense and be usable, might be interesting to include them here while explaining why i did what i did. Also would include a short paragraph on the frontend framework choice as this one wasn't as straightforward.

4.6 Logic Implementation

Here i'd put **everthing** i did before refactoring the codebase. This includes everything from the documentation until half of 12.8., like:

- Initial Database design
- Making the prototype configuration tool on the 3D Prototype with all it's logic
- Later moving it to Kivy (with the problems that came with that)
- Creation of the first Application Window and it's expansions
- Implementation of the Content Manager tool
- Database Redesign (and outlining the risk of SQL Injections which was later fixed)

While this list is somewhat chronological, i'm not sure if it makes sense to keep it that way. While during this time, i was mostly focused on finishing one program before starting another, i'm sure there was *some* jumping around, which would make more sense to just keep in its "subcategory" (like Content Manager tool implementation).

4.7 Refactoring

This might be the most interesting section as the learning curve of application development really took it's toll on the program up until this point and things became quite the spaghetti code, which was just unmaintainable and impossible to work with at this point, even for me as the creator.

I'd outline what the issue was, give some explanations on why this was happening and propose the plan i drafted up (and implemented) to mitigate this.

Some POI would be the management layers for topics and categories, the expansion of the database wrapper, and object management in code.

Obviously this all caused some issues after implementation with things i couldn't test at the time, but they were rather minor, so if i include them, i'd probably do it briefly.

Here i also fixed the SQL Injections.

4.8 Expanding Capabilities

This would include...

- the implementation of the searchbar
- naming categories in the configuration tool
- expanding the configuration tool with the ability to rename recorded categories
- expanding the category management layer with the necessary functions to facilitate the above and then some (namely creation and deletion)

These, too would include thoughts behind certain decisions and problems that were encountered and are worth mentioning (if any).

4.9 HID Integration

Implementing the Joystick controls was also pretty interesting, as it required some reverse engineering (if you could call that) of the communication with the library i chose. There was also some special design choices i made that i'd like to outline (e.g. using ENUMs to assign inputs). There's also one problem that i'd like to explain because it also led to an unusual but necessary choice in behavior.

As you can tell, there might be things missing. Namely the Guestbook, NFC reader, LEDS, Feedback mechanism and Multimedia support. This is obviously dependent on whether or not there will be another (albeit short) phase of development, where i might be able to finish one of these features. Which is also dependent on how much of the exposé i can reuse, as rewriting this in it's entirety would take up all the time i have left for this thesis.

I have written a paragraph about this in my documentation, which i would later include in the limitations section.

Chapter 5

Conclusion

I'm not sure what to put here but some things that come to mind are the final feedback from you as the stakeholder, as well as the limitations.

5.1 Limitations

For one, i'd like to go over the risk assessment plan in general and outlined how some risks were mitigated from the beginning, and how others were mitigated while/after they were encountered.

Then, how and why the actual implementation differed rather greatly from what was proposed/planned in the methodology section.

Later on i'd like to go over why certain features were dropped, though this strongly ties in with the "feature creep" part of the risk assessment plan so i might put it there.

I'll probably find some other things when i go through my notes and materials in detail. This is just a rough sketch that awaits your input :)

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