From Low Fidelity to High Fidelity Prototypes: How to Integrate Two Eye Tracking Studies into an Iterative Design Process for a Better User Experience

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Abstract: The aim of this study is to investigate the effectiveness of an iterative evaluation design process using low-fidelity prototypes (LFPs) and high-fidelity prototypes (HFPs) for a learner dashboard (LD) to improve user experience (UX) within an eye-tracking study with thinking aloud. The LD itself is designed to support online students in their learning process and self-regulation. Two studies were conducted, Study 1 focused on an LFP and Study 2 on the HFP version of the prototype. The involved participants (n=22) from different semesters provided different perspectives and emphasized the importance of considering heterogeneous user groups in the evaluations. Key findings included fewer adjustments required for the HFP, highlighting the value of early evaluation and iterative design processes in optimizing UX. This iterative approach allowed for continuous improvement based on real-time feedback, resulting in an optimized final prototype that better met functional and cognitive requirements. Comparison of key concepts across both studies revealed positive effects of methodological improvements, demonstrating the effectiveness of combining early evaluations with refined approaches for improved UX design in learning environments.

1 INTRODUCTION

In recent years, there has been a growing interest in understanding how users interact with digital products and services, which are becoming more and more common in everyday life. This is partly driven by their ubiquity in different domains and the emergence of new technologies and applications (Goodwin, 2009), (Mohammed & Karagozlu, 2021).

To gain insight and a deeper understanding of how users behave and interact with a digital tool such as a Learner Dashboard (LD), methods such as eye-tracking with thinking-aloud techniques can provide valuable insights that can then be used to refine the design (Drzyzga et al., 2023), (Toreini et al., 2022). The LD is being developed as a plug-in to a Learning Management System (LMS) for a university network in higher education and is intended to help online students with self-regulation and also to reduce dropout (Drzyzga et al., 2023). It has been developed through an iterative user-centered design (UCD) process in collaboration with the students who will use it (Drzyzga & Harder, 2023). As part of this iterative process, a second thinking aloud eye-tracking study was conducted as a follow-up study using a modified design prototype version of the LD. Both studies are designed to understand users' cognitive effort in digital learning environments.

Figure 1 shows the research object used in study one to investigate the development of a design prototype based on a low-fidelity prototype (LFP) (Drzyzga & Harder, 2022). After the development of the LFP, the prototype was reviewed on several levels. Based on the results of the LFP version, a high-fidelity prototype (HFP) was designed as shown in Figure 2. This formed the basis for the evaluation of Study 2. Such iterative approaches based on different fidelities (Figure 1) provide an opportunity to see if previous design decisions are going in the right direction and if adjustments need to be made (Bergstrom et al., 2011).

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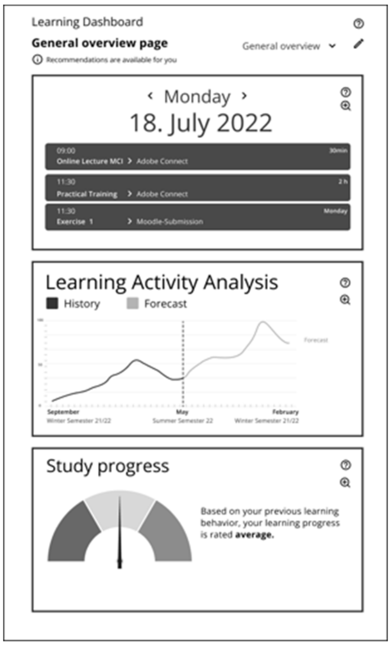

Figure 1: The LFP LD version (named here "Learning Dashboard") (Drzyzga & Harder, 2022).

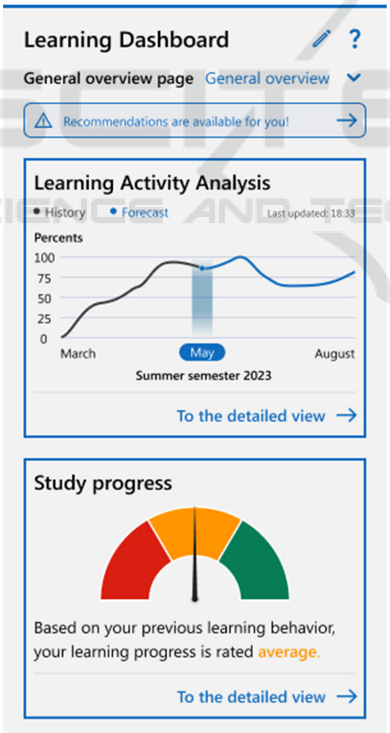

Figure 2: The HFP version (named here "Learning Dashboard").

Wireframes, such as the one shown in Figure 1, do not need to be to scale initially (Hartson & Pyla, 2018), so the different widths, for example, are a result of focusing on functionality in the first version and adapting to the later page layout in the HFP version.

An important interest of this study was the degree of validity of the approach despite the different stages of development of the prototype. In this context, the following research question (RQ) and goals emerged:

1. How does an iterative design process that includes both an LFP and HFP improve the identification and resolution of usability problems compared to using only one type of prototype?
2. How do the insights gained from interactions with the LFP differ from those gained from HFP evaluations? Do these differences affect the effectiveness and efficiency of solving usability problems at different stages of development?
3. How does iterative evaluation with LFP and HFP maintain consistency across participant groups, such as students from different semesters or backgrounds?

The aim is to investigate how the eye-tracking studies conducted on the LFP and HFP lead to less significant usability problems being identified in subsequent evaluations. Secondly, to identify differences in general layout organisation and interaction design concerns when interacting with LFPs as opposed to HFPs, which focus more on screen clarity, learning progress information and overall user experience (UX). A third key objective is to examine the iterative evaluation with LFPs and HFPs and whether it provides consistent usability findings across participant groups, minimising the impact of group differences on perceptions, opinions and feedback.

2 METHOD

To ensure methodological rigor in this study, the usability and UX of an LFP and an HFP were compared and contrasted using a mixed methods approach that combined eye-tracking and thinking-aloud techniques (Figure 3). This allowed the research questions related to prototyping learning dashboards to be addressed while leveraging the strengths of both quantitative and qualitative data collection methods.

The two studies recruited students from a variety of classes and backgrounds for a total of 22 participants. This was done to ensure that the results could be generalized across different user groups and to minimize the impact of group differences.

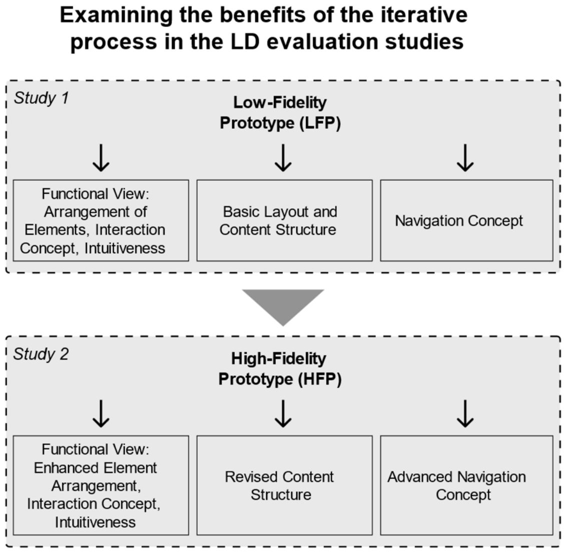

Figure 3: Evaluation process for the two studies.

3 CONDUCTING AND SETTING UP THE TWO STUDIES

The two studies were preceded by clear objectives, the formulation of their research questions to guide the studies, and a thorough literature review to contextualize the research within existing knowledge of digital learning processes. This included analysis, prototype design, eye-tracking methods and thinking aloud techniques. This formed the basis for the design of two sequential studies by evaluating the LFP and HFP. Upon completion of both studies, the data sets were analyzed to provide quantitative and qualitative insights into the user behavior and cognitive processes associated with each prototype.

The Participants were able to use their own visual acuity using the "Tobii Pro Glasses 3" glasses[1]. They were seated approximately 70 cm from the monitor to obtain optimal results. Calibration and validation of the correct position, gaze direction and consideration of external conditions (e.g., reflections, sunlight) were performed before the start of the experiments (Figure 4). To avoid any disruption to the study, a protocol was drawn up by the research assistants for taking notes (Drzyzga et al., 2023).

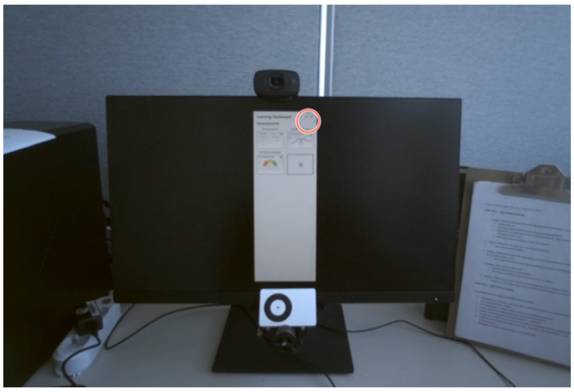

Figure 4: Eye-tracking test with HFP open and card editing view (red circle indicates user's viewpoint).

A total of ten participants (6 male, 4 female) took part in Study 1 and twelve participants (9 male, 3 female) in Study 2. In both in-person studies, the participants were students of a usability course in the 4th semester of a bachelor's programme that teaches e.g. conceptual thinking or digital media production ("*Information Technology and Design*"). They were asked to perform different tasks on the design prototype, which was provided during the session as a clickable graphical prototype in an internet browser. Prior to the studies, pre-tests were carried out with three participants each, for a total of two hours, to determine whether the task design and interview questions were suitable and understandable (Drzyzga et al., 2023).

The LFP consisted of 14 different views (wireframes) with contextual modalities and the HFP contained a total of 9 different wireframes with several contextual modalities to simulate a realistic usage context of the LD prototype. Study 1 was a one-day test and study 2 took a total of three days to complete, excluding preparation and follow-up activities. The studies followed ethical guidelines.

At the beginning of the study, participants were informed of the aims and objectives of the study. This included the scope and purpose of the study, as well as information about the project and the aim of developing a self-regulation LD as an open-source plugin for the LMS. The briefing took five minutes. All participants gave their consent for their data to be processed for this study. The subsequent evaluation took approximately 20 minutes each. At the end of the evaluation, the abbreviated version of the User Experience Questionnaire (UEQ-S) was filled in (Schrepp et al., 2017).

[1] https://www.tobii.com/products/eye-trackers/wearables/tobii-pro-glasses-3

Table 1: Comparison of some of the key concepts of the two studies with examples of improvements for the evaluation of the different prototypes (LFP & HFP).

Goal	Description	Study 1 Findings/Concepts (LFP)	Study 2 Findings/Concepts (HFP)	Improvements/Findings
1	Obtaining information about arrangement of elements, layout design, overall UX	Layout organization (e.g. icon placement)	Interaction design Intuitive navigation and labelling	Findings about improved UX due to better arrangement of elements, interaction design changes, clearer labels and easier to understand navigation in the HFP.
2	Evaluating the clarity of different views and learning progress information	Clarity of higher-level views (semester, study) Informed about learning status	Improved clarity Trustworthiness of recommendations	Findings show improved clarity in the HFP, trustworthy recommendations, and reduced missing information due to design improvements.
3	Assessment of the explanatory nature of adding/removing functionality for card editing	Clarity of general workflow	Revised functionality Clarity of used visual aspects (e.g. colors, icons)	Improved usability in HFP through more intuitive functionality. Colored prototype easier to evaluate.
4	Evaluating paths to content elements, return to start, labelling of interaction elements, navigation elements, orientation within the LD, and use of drop-down menus	Paths Return to Start Labelling Navigation elements Orientation Use of drop-down menus	Easier paths and return to Start Sufficient labelling Constant orientation within the LD	Improvements based on findings from both studies, highlighting the improved UX due to better pathfinding, return options, labelling and overall navigation in the HFP.
5	Evaluating help page content, clarity, scope of information provided, and completeness	Clarity of content Visibility of information	Clarity of content Visibility of information	Findings on improved help page design in the HFP.
6	Gathering general feedback	Ease of paths Ease of return to start Sufficiency of labelling Understanding of navigation Orientation within the dashboard Use of drop-down menus	Ease of paths Ease of return to start Sufficiency of labelling Understanding of navigation Orientation within the dashboard Use of drop-down menus	Additional findings about aspects of improvements made to the HFP.

Table 2: Comparison of some of the key concepts of the two studies with examples of improvements to the methodology used.

Goal	Description	Study 1 Findings/Concepts (LFP)	Study 2 Findings/Concepts (HFP)	Improvements/Findings
1	Obtaining information to optimize the methodology	Gaining insight into how to conduct a wireframe-based evaluation and focus on functional and cognitive requirements	Gaining insight into how to conduct a more complex prototype evaluation	Less moderation of interviews
2	Obtaining information about the iterative evaluation	Functional as a basis	Repetition based on an advanced prototype	The findings revealed that fewer (greater) adjustments had to be made later. Adjustments (e.g. interactions or functions) are easier to make in an LFP. In the HFP both would have to be tested.
3	Obtaining additional perspectives and opinions	Smaller group of participants	Smaller group of participants	Findings show that different groups of users/students (different semesters) resulted in different views and opinions.

4 RESULTS & ANALYSIS

The results of the two studies presented, which used the wireframe prototypes LFP and HFP to investigate the effectiveness of iterative development within a student-centered design approach in evaluating usability and overall UX in an LD, aimed to explore the implications of this combined approach. Several key findings emerged from Study 1, which focused on the LFP:

The LFP required fewer adjustments than the HFP, suggesting that interactions or features can be easily changed early in development without affecting later testing. This underscores the value of incorporating usability and UX evaluation early in the design process and emphasizes iterative procedures for potential UX improvements.

Students from different years provided different perspectives on the LD, demonstrating that involving users with different backgrounds or experiences is critical to gaining a full understanding of their needs and preferences. This finding reinforces the importance of considering heterogeneous user groups in UX evaluations.

The iterative design process allowed for continuous improvement based on real-time feedback from participants, resulting in an improved prototype that better met functional and cognitive requirements. This also underscores the effectiveness of integrating such evaluation approaches early in the LD development lifecycle.

Study 2 builds on Study 1 and incorporates minor methodological refinements, including reduced interaction during interviews to create a more natural UX with less investigator influence on participant responses. The key findings from this combined look at the conduct of both studies were:

As in Study 1, fewer adjustments were required for the LFP compared to the HFP, further emphasizing that interactions or features can be easily modified in early stages of development without affecting later stages of testing. This finding reinforces the value of early evaluation and iterative design processes in optimizing the UX of the LFP.

Also in this study, participants from different years provided different perspectives on the LD, as observed in Study 1, again highlighting the importance of considering different user groups in UX evaluations. The consistency of this finding across both studies underscores its importance.

As in Study 1, the iterative design process allowed for continuous improvement based on real-time feedback from participants, resulting in an optimized, functionally enhanced prototype at both the UI and cognitive levels.

A comparison of key concepts between the two studies (Table 1) revealed positive effects resulting from methodological improvements, such as less intervention during interviews and fewer adjustments required for the LFP compared to the HFP (Table 2). These improvements allowed for continuous improvement based on real user feedback, resulting in a final prototype that effectively addressed the functional and cognitive requirements identified by participants with different backgrounds or experiences. The combination of early evaluations using LFPs with methodological refinements led to an optimized product, demonstrating the value of iterative approaches in UX design for LDs.

The RQs identified in this study can be answered as follows:

For RQ1, the use of the iterative design process improved the detection and resolution of usability issues substantially compared to using only one type of prototype, resulting in fewer major issues in the subsequent evaluations.

For RQ2, interacting with the LFP primarily identified general layout organisation and interaction design concerns, while the HFP provided more accurate insights into specific visual elements, clarity of views, learning progress information and overall UX.

For RQ3 it could be concluded that the iterative evaluation approach minimised the impact of group differences on perceptions, opinions and feedback by maintaining consistency across different participant groups, such as students from different years or background.

These first findings demonstrate the benefits of an integrated approach to prototyping in design processes. By combining LFPs and HFPs, usability problems can be identified and resolved more effectively, while minimizing development effort and ensuring a consistent understanding of user needs across different user groups. Finally, this work provides valuable insights for optimizing design workflows by adopting an iterative approach that maximizes efficiency in solving usability challenges at different stages of the development process.

5 DISCUSSION & OUTLOOK

The approach presented provided valuable insights into the evolving usability/UX of the LD and helped to identify potential issues early in the development process.

When comparing the LFP and HFP, improvements were observed in various aspects of the LD, including layout organization, clarity of information presentation, functionality, navigation and help page design. Although conducting separate studies, as was done here, may take more time and effort to plan, administer, transcribe and analyze, it has advantages such as the early identification of functional and cognitive problems through the LFP, including the findings and improvements listed. This iterative approach, with increasing levels of detail as development progresses, was also seen as an advantage by (Hartson & Pyla, 2018), for example in deciding on initial ideas. Although there are some advantages to starting with such an LFP based on wireframes, users have suggested that a colored prototype might be easier to evaluate. In the second study using the HFP, it was possible to focus development on application details and reduce the workload by spreading participants over several days. Bergstrom et al. stated that further iterations could also create new problems, which in this case could not be immediately identified in the quantitative / qualitative iteration (Bergstrom et al., 2011). This could be an advantage of combining these methods in this way. Through an understanding of cognitive effort and user behavior, more effective and efficient interfaces can be developed that are designed to support the learning experience of students and to enable self-regulation.

5.1 Limitations

The effectiveness of the study with two user groups may not generalize well without further testing in different educational contexts and stages of development. There may also be issues with subjectivity with qualitative methods such as interview techniques. Additional appropriate metrics would need to be considered to accurately measure UX improvements. The approach itself should consider or incorporate aesthetics and emotional responses in addition to usability. Despite these limitations, an iterative approach is still valuable for improving the usability of educational technology through continuous research and collaboration between stakeholders.

5.2 Potential Areas for Future Research

Future studies could further explore the impact of iterative design processes on usability and UX by including additional methods or comparing different levels of fidelity in more detail. Testing different methods, as was done, can provide additional insight into user behavior and preferences, leading to more effective design solutions. More research may be needed to investigate the optimal number of iterations or stages in such a development cycle, and the ideal balance between user involvement and time efficiency. This could help to determine whether there are more efficient strategies that still provide valuable insights for improving usability/UX design. Questions remain as to whether a single study approach with more participants could have produced similar results, or whether the addition of another iteration step might have provided additional benefits. These open questions provide opportunities to explore alternative development strategies and further refine the process in future studies.

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