User-Centered Design and Iterative Refinement: Promoting Student Learning with an Interactive Dashboard

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Abstract: The study uses a user-centered design methodology to develop a prototype for an interactive student dashboard that focuses on user needs. This includes iterative testing and integration of user feedback to develop a usable interface that presents academic data in a more understandable and intuitive manner. Key features of the dashboard include academic progress tracking and personalized recommendations based on machine learning. The primary target audience is online students who may study in isolation and have less physical contact with their peers. The learner dashboard (LD) will be developed as a plug-in to the university's learning management system. The study presents the results of a workshop with students experienced in human-computer interaction. They evaluated a prototype of the LD using established interaction principles. The research provides critical insights for future advancements in educational technology and drives the creation of more interactive, personalized, and easy-to-use tools in the academic landscape.

1 INTRODUCTION

In recent years, digital study offerings have become increasingly important, which is partly due to the fact that students can individually organize their learning process (Getto et al., 2018). This gives students the opportunity to learn largely independent of time and place, thus offering them more flexibility (Wannemacher et al., 2016). The digital nature of online learning and the delivery of learning content via the Internet creates a physical distance. As a result, students often do not have the opportunity to learn with other peers or to contact instructors in person to discuss learning outcomes (Koi-Akrofi et al., 2020; Kaufmann and Vallade, 2021) for example. This paper presents a user-centered design (UCD) approach to a learner dashboard (LD) that is being developed as a plug-in to a learning management system (LMS) of a higher education network to support online students in their learning process (Janneck et al., 2021). It highlights the benefits of research that involves students in identifying and solving problems related to its functionality and interaction. In the field of educational technology, the terms "learner dashboard" and "learning dashboard" are often used synonymously. However, there are some subtle differences in terminology. The term "learner dashboard" focuses more on the perspective of the individual learner. It is an individualized tool that allows students to monitor their own progress, set goals, and adjust their learning strategy. This supports, for example, self-regulated learning (Matcha et al., 2019; Viberg et al., 2020). In contrast, the term "learning dashboard" is commonly used to describe digital tools for visualizing data about learning. It is used by educators to track, understand, and improve student learning. It can display data about student performance, engagement, and learning progress (Siemens and Baker, 2012, Verbert et al., 2014). We will use the first definition in this paper as the dashboard we are developing takes more of a learner's - in our case, student's - perspective by, among other things, providing opportunities for self-regulation (Lehmann et al., 2014; Barnard-Brak et al., 2010).

In the study, students were asked to evaluate an interactive prototype of the LD based on wireframes according to the design and interaction principles outlined in EN ISO 9241-110:20201. The principles are

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[1] ISO 9241-110:2020 (en) Ergonomics of human-system interaction — Part 110: Interaction principles, https://www.iso.org/standard/75258.html, accessed June 20, 2023

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established heuristics and are described as the "Ergonomics of human-system interaction - Part 110: Interaction principles". It is a standard that describes principles of interaction between a user and a system that are formulated in general terms, independent of situations of use, application, environment or technology. The seven interaction principles are: Suitability for the user's tasks, Self-descriptiveness, Conformity with user expectations, Learnability, Controllability, Use error robustness and User engagement. The study is part of a multi-stage UCD design approach with evaluations ranging from traditional design principles to eye-tracking studies of cognitive requirements in the area of usability and user experience (UX) testing and analysis (Drzyzga & Harder, 2022). The aim of the study was to encourage students to participate in the development of the LD and to improve its accessibility and intuitiveness by taking into account their expertise. By involving students early on, interaction issues can be identified and discussed, ensuring that the usability of the LD can be effectively optimized at an early stage. As argued in the workshop by Verbert et al. 2020, it is important to use an iterative, user-centered approach, focusing first on UX and then on impact evaluation, to avoid biasing the results. In this phase of our design study, we focused on an interactive UX exploration. We wanted to identify potential problem areas, points of failure that could prevent a smooth interaction between the user and the LD. These could range from functionality issues to interface design challenges, from cognitive or information overload (Chen et al., 2011; Shrivastav and Hiltz 2013) to lack of intuitive navigation. We wanted to find ways to make the LD more intuitive, more accessible and to enhance the usability. This analysis was a thorough and iterative process that involved active student participation, continuous feedback. The data collected was then processed and turned into deliverables. These insights formed the basis of our recommendations for the development and improvement of the LD, ensuring that it is aligned with user needs and preferences.

2 METHOD

The methodological approach included a four-step process consisting of the definition of the scope of prototype evaluation, pre-evaluation preparation sessions, the evaluation and careful analysis of feedback to identify the interaction with the prototype on the seven interaction principles. The research in this study focused on the interactions with the prototype. The prototype itself was developed as a clickable prototype based on literature research, expert interviews and subsequent evaluation of wireframes.

2.1 Definition of the Scope of the Evaluation of the Prototype

To evaluate the validity and effectiveness of our interactive design, we made the prototype (Figure 1) available to 24 students enrolled in a human-computer interaction (HCI) module. We chose this course for our study because the target group - online students, in mixed age and gender groups - applied for it. The students who participated in the workshop were undergraduate students in the university's online Media Informatics program. They were asked to solve the following problem:

"Evaluate the prototype on the basis of the interaction principles (dialog principles) according to DIN EN ISO 9241-110. Using concrete examples, explain to what extent a principle has been implemented positively or negatively. In case of negative aspects, give suggestions for improvement".

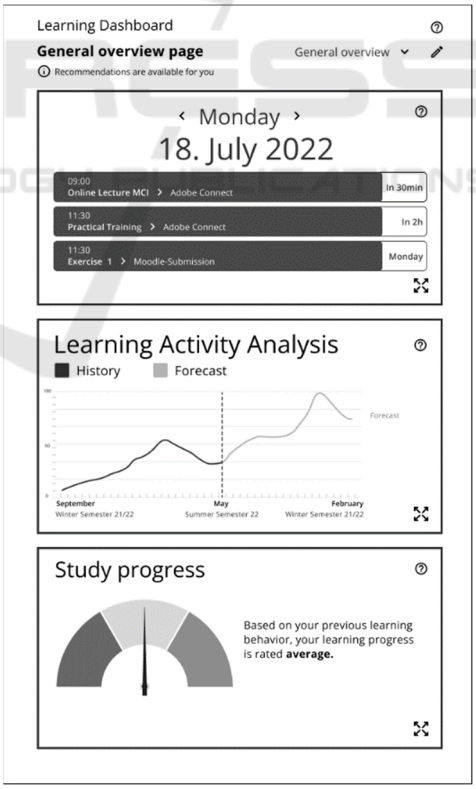

Figure 1: LD's wireframe used in the workshop with three cards (calendar, learning activity analysis, study progress).

The results of the evaluation were copied by the students as text into a submission field in the LMS of the university. This was followed by a group discussion.

Under the guidance of a university instructor, they were prepared for the workshop topics by reviewing the course script and participating in weekly one-hour web conferences to discuss related topics (e.g., Usability, HCI). Successful completion of the half day workshop was required to register for the final exam of the course. This assignment was specially designed and delivered via a four-hour online workshop using an Internet browser. To ensure academic rigor and maintain the integrity of the evaluation process, the entire process was supervised and monitored by three studied faculty members.

2.2 Pre-Evaluation Preparation

The pre-evaluation phase was designed to prepare students for the upcoming evaluation process. The workshop was scheduled so that the students would have acquired the necessary expertise. The faculty members made sure that the students understood these principles well and knew how to apply them during the evaluation process.

2.3 Evaluation Process

The evaluation process itself consists of two parts. The first part was the students' interaction with the prototype and exploration of its various features. The second part was their evaluation of the prototype on the basis of the seven interaction principles.

2.4 Post-Evaluation Analysis

In the post-evaluation analysis, two of the three qualified faculty members in Media Informatics, experienced in usability and UX, analyzed the students' feedback. They looked for any patterns or recurring themes that the students found during their interaction with the prototype. The feedback was thoroughly analyzed. On completion of the study, the necessary changes were made to the prototype based on the results of the feedback. However, the analysis went further to uncover the underlying factors that influence user interaction, engagement, and overall satisfaction. In our study, we took a similar approach, carefully examining each aspect of the LD's functionality.

3 DEVELOPING THE LD IN A COLLABORATIVE DESIGN PROCESS

The LD has been carefully designed with a focus on key interaction elements. We will describe the key interaction elements, the collaborative design tool used, and the positive impact of iterative testing on the overall design process.

3.1 Interaction Elements of the LD

The LD interface, and in particular the cards offered, are driven by interaction elements such as the question mark icon, the zoom-in / zoom-out-icons, the pencil icon, and the menu. In order to provide an engaging and interactive UX, these elements have been well selected and designed with clickable functionality. The question mark icon was added to provide immediate help and guidance when needed, while the zoom-in / zoom-out-icons allows the user to easily examine data and details in more detail. The pencil icon at the top of the LD was added to allow users to add or delete cards, and the menu was designed to ensure easy navigation through the LD.

3.2 The Collaborative Design Tool

In order to create these interactive elements, we used a tool for the collaborative design of interfaces[2]. This tool, with its ability to generate interactive prototypes, is well known in the digital design community. We used this tool because it allowed us to implement the ideas and developments so far in a collaborative way, both synchronously and asynchronously.

3.3 Iterative Testing and Its Impact

The iterative testing feature of the design tool was important for our design process. It allowed us to test prototypes in real time, gather feedback, make necessary adjustments, and retest, thus promoting an environment of continuous improvement.

4 DEVELOPING WITH USER FEEDBACK IN MIND

UX analysis was an important part of our study. It provided critical insights for the redesign process. The value of such an analysis, as highlighted in our

[2] https://www.figma.com/, accessed June 20, 2023

study, reinforces that UX analysis is a necessary part of design (Vlasenko et al., 2022; Luther et al., 2020).

4.1 The Role of Wireframing in User Interface Development

Conceptualizing and refining a wireframe is an essential step in the development of an interactive user interface. According to Hampshire et al. (2022), wireframes provide representations of the design, it's a representation of how the structure, layout, content and function of the product could be. The developed wireframe served as a basic structure for the subsequent development stages of the LD, and also as a visual guide that represented the basic structure of the LD. It allowed us to plan the upcoming layout and interaction patterns in detail.

4.2 Development of an Interactive Prototype

The creation of a low-fidelity, interactive proto-type was the next step after the wireframe refinement. The final prototype of the LD at this stage of our development process was featured with 14 different views, each of which was designed with a specific purpose in mind to enhance the user's learning process. These views were complemented by a series of modal dialog boxes, each of which prompted the user for specific input or provided critical information.

5 RESULTS

A summary of the results is given in Table 1 and is explained in detail in the following chapters. In total, a comprehensive 54-page ISO 216 A4 report carefully summarizes the anonymized results of the student evaluations. It presents what the students found and suggests possible further improvements. It should be noted that not all students wrote something on each of the 7 interaction principles, which may be due to the limited time available.

5.1 Suitability for the User's Tasks

The interaction principle "suitability for the user's tasks" was evaluated differently by 5 of the students. Some described the evaluation as positive, while others found the system inappropriate. It seems that the system tries to collect user data mainly through information input. This can lead to a high workload for users who spend a lot of time with the material. Some students have suggested improvements, such as automatically disconnecting from the system after a certain amount of time, or the ability to control the collection of relevant information when the material is used offline as a PDF or the misinterpretation of the calendar view where the bar was interpreted as remaining time – what it was not intended (Figure 2).

Table 1: Summary of the results.

Interaction Principle	Keywords
Suitability for the user's tasks	reducing nested information, measuring workload (e.g., offline learning), user data/analysis of learning activities (e.g., optional data logging by own inputs), calendar view (see Fig. 2, not easy to understand (the bar was interpreted as remaining time – what it was not intended))
Self-descriptiveness	clear understanding (e.g. of predictions), navigation line (e.g., breadcrumb), prominent recommendation, unique headings, confusion (e.g., position vs. functionality: close button and enlargement of the content, see Fig. 1 icon in top right corner of card), intuitive icon (e.g., zoom-in/zoom-out icon vs. maximizing), drop-down list (labeling), semester/module Information, accurate predictions need refinement, improved clarity and usability, small bar at top of details pane
Conformity with user expectations	back button, consistent placement, layout confusion (e.g. close-button vs „enlarged"-icon, see Fig. 1 top right corner)
Learnability	intuitive delete function (calendar view or edit card function (not clear where to add new card)), inconsistent information (e.g. interaction elements vs info-elements), text to long (limits the overview, see Fig. 3)
Controllability	automatic logout, clear navigation, undo option, controllability of adding and deleting cards
Use error robustness	date format, spell checker, prompting whether an action is to be performed, option to reset to original state
User Engagement	learning progress (e.g. information-based vs diagrams), clarity of interface

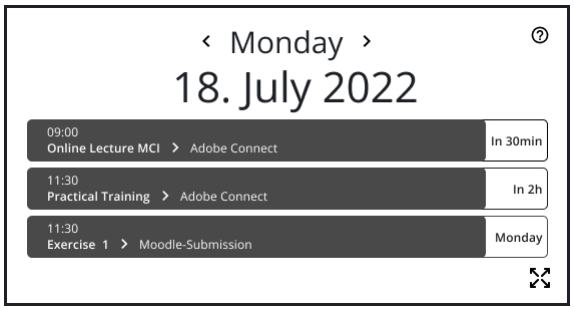

Figure 2: Calendar view (LD-Card).

Others have commented positively on the calendar view of the dashboard, which provides relevant information, and the analysis of learning activities, which can help improve learning progress. It seems that students value different aspects of the interaction principle, resulting in a mixed evaluation.

5.2 Self-Descriptiveness

The interaction principle "self-descriptiveness" was evaluated differently by 17 of the students. It was stated that the icons needed more textual labels for a clearer understanding of the functionalities. A "return to start" button and a navigation line indicating the user's current location would improve system orientation. The recommendation section should be more prominent to improve UX. Distinguishing different views with unique headings would eliminate confusion. The maximize arrows should be replaced with a more intuitive icon. Semester/module selection should be more highlighted. The learning activity analysis graph needs refinement for accurate predictions. More information on individual semester/module tiles and an improved calendar feature to detect completed dates would improve clarity and usability. Finally, a small bar at the top of the details pane would improve functionality by allowing view selection when details take up the entire screen.

5.3 Conformity with User Expectations

The interaction principle "conformity with user expectations" was evaluated differently by 16 of the students. Several areas for improvement were identified from student feedback on the usability of a prototype. One issue that the students found inconsistent and confusing was the positioning of the back button. They suggested that consistent placement of the back button could significantly improve the UX. The visibility of fields was also a concern. The students felt that their interaction with the prototype was hindered by the fact that important fields were not easily accessible. They recommended a design change to make these fields more accessible. The icon selection and calendar view were also criticized by the students. They found the icons unclear, which made it difficult to understand their functions. Meanwhile, the calendar view was considered inadequate and the students suggested improvements to make it more user-friendly. Students also noted problems with navigation and closing. Navigating was found to be misleading and closing was found to be less intuitive. Students felt that the usability of the prototype could be greatly improved with better navigation design and a more straightforward close function. Problems were also found with the detail view and certain featureless functions. The students felt that the detail view could be improved to provide more relevant information, and the non-functional features were seen as unnecessary and confusing.

5.4 Learnability

The interaction principle "learnability" was evaluated differently by 21 of the students. They provided feedback on the learnability of the prototype was insightful and highlighted several areas for improvement. One notable concern was the lack of an intuitive delete function, which caused some confusion. The interface layout was also found to be confusing, and inconsistencies in module information added to the confusion. In order to address these issues, the students have suggested a number of improvements. They suggest introducing short help texts to guide users through the interface and better illustrate the features. Some graphics are explained in full-screen mode, and long texts open up again, making it difficult to keep track. They also recommend moving the detailed explanations of the graphs to a more logical and user-friendly layout. Another popular suggestion was to provide more prominent access to progress recommendations. This would improve the transparency of the tool. In addition, students suggested adding a semester or module selection feature, which could greatly improve the tool's usability. The ability to manipulate tiles was also mentioned, as was the need for clear instructions on how to use the system. Students felt that these changes, along with the addition of visual cues, could help users navigate the tool more easily. The idea of an introductory tutorial was also raised. This could guide new users through the tool, explaining its features and how to use them. Mouse hover assistance was also suggested as a way to improve learnability.

5.5 Controllability

The interaction principle "controllability" was evaluated differently by 7 of the students. In terms of controllability, students noted that that an automatic logout feature should be implemented to ensure that users do not accidentally leave the application open and waste resources. They suggested that there should be a clear way for users to return to the default setting, such as allowing them to move tiles back to their original position. Ensure that all buttons can be used for control purposes, including providing an "escape" button to allow users to navigate back to the previous page. They also noted to consider adding a "back" button or arrow on the page, especially when using a smartphone, as it provides a clear way for users to navigate back in their browsing history. Providing a direct undo option to restore removed tiles, rather than requiring users to go through an editing and dialog process. Feedback indicates that they would like to remove individual influencing variables from the grading or change the percentage grading as this may be useful for certain modules where users are not using the learning material. However, this would not be indicative of the student's actual learning progress if the student were to make extensive use of the instructor's tutorials and weekly web conferences. It was noted that the controllability of adding and deleting cards in the LD could be increased by allowing users to navigate out of edit mode without having to precisely click the pencil icon in the top right corner again, as this can be frustrating for users who may accidentally exit edit mode.

5.6 Use Error Robustness

The interaction principle "use error robustness" was evaluated differently by 4 of the students. The students noted that the prototype has room for improvement in terms of error robustness, since the user can make different entries in the calendar and there is a possibility of errors in the date format. A logical date format should be used and a spell checker should be implemented to avoid errors. Regarding the editing of the LD's cards, it is judged that deleting a card is easy, but an additional prompt such as "Are you sure you want to remove the calendar card?" could be added to ensure that the user's intent is clear. The prototype has no way to enter custom tasks, which limits the robustness of the input masks. A feature like "Reset to original state" could improve this significantly by allowing the user to reset all items individually if they are accidentally deleted.

5.7 User Engagement

The interaction principle "user engagement" was evaluated differently by 13 of the students. Based on the individual statements, it can be concluded that the interaction principle of "user engagement" has been implemented to varying degrees, both positively and negatively. Some students appreciate the potential of the prototype to increase motivation and engagement through concrete examples such as the display of learning progress and recommendations for improvement. Others express concerns about the clarity of the interface, the need for further explanation of how certain information is calculated, and the potential for distraction from the learning content. Overall, there seems to be a mixed response to the implementation of this interaction principle.

6 DISCUSSIONS

The aim of the study was to examine an LD at an early stage of development for possible interaction inconsistencies. To do this, we gave the developed LD to 24 online students, who could also be the later users, when the LD is integrated into one or more of their courses. They had to evaluate the LD in a half-day workshop based on the seven interaction principles of EN ISO 9241-110:2020. The students' feedback highlights the importance of applying a UCD approach to the development of an LD. This is consistent with the findings of Vesin et al. (2018), who emphasised the importance of UCD in creating adaptive learning systems. These findings helped us to conduct an UX analysis and provided us with valuable insights, which we were able to use to refine the prototype. The issues identified suggest that the prototype can benefit significantly from refinement of its user interface and functionality. In summary, it is clear from this evaluation that there is great value in having a tool evaluated user-centered by students, for students, as only they know the challenges of student life. In addition, due to the course's focus on fundamental HCI topics, participants had background knowledge that, combined with their student-centered perspective, enabled them to evaluate the UX of the LD and provide informed feedback. The results show that the research could be repeated in the same way as part of the design study, but it has to be taken into account that the time available was not sufficient for all students, as shown by the different number and partly reduced length of feedbacks on the individual interaction principles. Also, the population may not be generalizable to all online students.

7 OUTLOOK

Through the feedback received, we are able to implement optimizations that could significantly improve the user interface, help features, and result in an overall improved UX to better meet user expectations. Taken together, these improvements could significantly increase usability, intuitiveness, and intelligibility to provide a tool that does not overwhelm the user. Furthermore, it would help them to reflect on and gain insight into their own learning process in the isolated environment in which online students often find themselves. As we move forward, it is important to continue to engage with students and iteratively refine the tool based on their feedback. After the optimization and subsequent further development of the LD, we will take a look at the cognitive demands of using the LD to also question the psychological aspects.

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REFERENCES

Barnard-Brak, L., Paton, V. O., & Lan, W. Y. (2010). Profiles in self-regulated learning in the online learning environment. International Review of Research in Open and Distributed Learning, 11(1), 61-80.

Caddick, R., & Cable, S. (2011). Communicating the user experience: A practical guide for creating useful UX documentation. John Wiley & Sons.

Chen, C. Y., Pedersen, S., & Murphy, K. L. (2011). Learners' perceived information overload in online learning via computer-mediated communication. Research in Learning Technology, 19(2).

Courage, C., & Baxter, K. (2005). Understanding your users: A practical guide to user requirements methods, tools, and techniques. Gulf Professional Publishing.

Drzyzga, G., & Harder, T. (2022). Student-centered Development of an Online Software Tool to Provide Learning Support Feedback: A Design-study Approach.

Getto, Barbara, Patrick Hintze, und Michael Kerres. (2018). (Wie) Kann Digitalisierung zur Hochschulentwicklung beitragen?

Hampshire, N., Califano, G., Spinks, D. (2022). Wireframes. In: Mastering Collaboration in a Product Team. Apress, Berkeley, CA. https://doi.org/10.1007/978-1-4842-8254-0_45

Janneck, M., Merceron, A., Sauer, P. (2021). Workshop on addressing dropout rates in higher education, online – everywhere. In Companion Proceedings of the 11th Learning Analytics and Knowledge Conference (LAK 2021), pp. 261–269

Kaufmann, R., & Vallade, J. I. (2021). Online student perceptions of their communication preparedness. E-learning and Digital Media, 18(1), 86-104.

Koi-Akrofi, G. Y., Owusu-Oware, E., & Tanye, H. (2020). Challenges of distance, blended, and online learning: A literature-based approach. International Journal on Integrating Technology in Education, 9(4), 17-39.

Lehmann, T., Hähnlein, I., & Ifenthaler, D. (2014). Cognitive, metacognitive and motivational perspectives on preflection in self-regulated online learning. Computers in human behavior, 32, 313-323.

Luther, L., Tiberius, V., & Brem, A. (2020). User Experience (UX) in business, management, and psychology: A bibliometric mapping of the current state of research. Multimodal Technologies and Interaction, 4(2), 18.

Matcha, W., Gašević, D., & Pardo, A. (2019). A systematic review of empirical studies on learning analytics dashboards: A self-regulated learning perspective. IEEE transactions on learning technologies, 13(2), 226-245.

Shrivastav, H., & Hiltz, S. R. (2013). Information overload in technology-based education: A meta-analysis.

Siemens, G., & Baker, R. S. D. (2012, April). Learning analytics and educational data mining: towards communication and collaboration. In Proceedings of the 2nd international conference on learning analytics and knowledge (pp. 252-254).

Verbert, K., Govaerts, S., Duval, E., Santos, J. L., Van Assche, F., Parra, G., & Klerkx, J. (2014). Learning dashboards: an overview and future research opportunities. Personal and Ubiquitous Computing, 18, 1499-1514.

Verbert, K., Ochoa, X., De Croon, R., Dourado, R. A., & De Laet, T. (2020, March). Learning analytics dashboards: the past, the present and the future. In Proceedings of the tenth international conference on learning analytics & knowledge (pp. 35-40).

Vesin, B., Mangaroska, K., & Giannakos, M. (2018). Learning in smart environments: user-centered design and analytics of an adaptive learning system. Smart Learning Environments, 5(1), 25. DOI:10.1186/s40561-018-0071-0

Viberg, O., Khalil, M., & Baars, M. (2020, March). Self-regulated learning and learning analytics in online learning environments: A review of empirical research. In Proceedings of the tenth international conference on learning analytics & knowledge (pp. 524-533).

Vlasenko, K. V., Lovianova, I. V., Volkov, S. V., Sitak, I. V., Chumak, O. O., Krasnoshchok, A. V., ... & Semerikov, S. O. (2022, March). UI/UX design of educational on-line courses. In CTE Workshop Proceedings (Vol. 9, pp. 184-199).

Wannemacher, Klaus, Imke Jungermann, Julia Scholz, Hacer Tercanli, und Anna von Villiez. (2016). „Digitale Lernszenarien im Hochschulbereich".