Fostering Collaborative and Creative Design of Learning Dashboards: An Empowered Participatory Approach and Tools

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Abstract

Learning dashboards play a crucial role in supporting decision-making throughout the learning process. However, their widespread adoption has been limited, which can be attributed to their relatively recent emergence and the lack of stakeholder involvement in the design process. To address this challenge and promote user engagement, we propose an integrated approach that combines a participatory design tool for the ideation phase and a generative tool for prototyping. In this study, we present an in-depth analysis of these two tools, focusing on their usability, ability to foster stakeholder participation, and overall user experience across different design phases. The participatory design tool enables end users, including teachers, researchers, and instructional designers, to actively contribute their insights, preferences, and requirements during the ideation phase. By incorporating their perspectives from the outset, we aim to create learning dashboards that align with their needs and expectations. Additionally, we introduce a generative tool specifically designed for prototyping learning dashboards. This tool empowers developers and designers to translate the ideas generated during the ideation phase into functional prototypes. It streamlines the prototyping process and enables rapid iteration and refinement based on user feedback. By facilitating the translation of ideas into tangible prototypes, we aim to bridge the gap between end users and developers, ensuring that the resulting learning dashboards meet their expectations and requirements. To evaluate the effectiveness of these tools, we conducted a comprehensive analysis of feedback received from participants who engaged with the participatory design tool during the ideation phase and the generative tool during the prototyping phase. The analysis focuses on key aspects such as usability, support for participation, and overall user experience. The findings demonstrate that these tools not only facilitate active end-user participation but also enhance the user experience of developers and designers involved in the dashboard creation process. The results of this study underscore the importance of stakeholder involvement in the design of learning dashboards and highlight the value of integrating participatory design approaches and generative tools. By actively involving end users and leveraging their insights, we can foster the development of

learning dashboards that better meet their needs, enhance their engagement, and ultimately improve the effectiveness of the learning experience.

Keywords:
Learning Dashboards – Participatory design – Generative design – Dashboard generation

1 Introduction

Learning Analytics Dashboards (LADs) play a crucial role in supporting decision-making throughout the learning process by organizing and presenting data indicators related to learners, learning processes, and learning contexts [Schwendimann et al., 2017]. Extensive research has demonstrated that well-designed learning analytics dashboards have the potential to significantly enhance the effectiveness of learning experiences by providing valuable insights and support to both learners and instructors. These dashboards serve as powerful tools for sustaining learning, identifying areas for improvement [Sadallah et al., 2020], and making informed decisions. Additionally, instructors can utilize the data and visualizations provided by these dashboards to compute meaningful reading and behavioral indicators [Sadallah et al., 2015]. This enables them to develop a comprehensive understanding of learners' performance, identify struggling students and areas of the course that require improvement, and deliver precise interventions.

Despite their potential benefits, the widespread adoption of learning analytics dashboards remains limited, primarily due to their relatively recent emergence and the lack of stakeholder participation in the design process [Alhamadi, 2020, Echeverria et al., 2018, Alvarez et al., 2020]. To address this challenge, participatory design, derived from user-centered design principles, has gained significant interest as an approach for developing effective learning analytics dashboards. Participatory design fosters consensus building and shared mental models among stakeholders, promoting the appropriate use of information in the design process. However, the implementation of participatory design in educational contexts is relatively rare, primarily due to the lack of clear approaches and tailored tools to meet its specific needs [Sarmiento and Wise, 2022, Dollinger et al., 2019].

In this context, our project aims to develop and support a design process for LADs by proposing a suite of tools that includes a participatory design tool for the ideation phase and a generative tool for the prototyping phase, centered around a shared design space. To validate the effectiveness of this suite, we analyze the tools in terms of usability, support for participation in the ideation phase, and user experience in the prototyping phase.

Following a Design-Based Research (DBR) methodology [Wang and Hannafin, 2005], our research consists of iterative cycles of design, implementation, and analysis. The initial iteration [Gilliot et al., 2018] validated the design process and the feasibility of integrating an ideation tool and a prototyping tool within a design space [Shaw, 2012]. The current iteration aims to

refine the design space, propose the PaDLAD ideation tool to facilitate the expression of the decision-making process and cooperation, develop the operational LADStudio prototyping tool, and analyze these tools.

The subsequent sections present the design methodology, the underlying LAD model, and the tools designed to support participatory design of LADs. We also describe the experiments conducted to analyze these tools and validate their usage.

2 Participatory and Generative Design of LADs

2.1 Design Methodology

Our approach combines two complementary design approaches: participatory design and generative design. Participatory design in education involves involving learners, educators, institutions, researchers, and developers in the different stages of the design process, from exploration to actual implementation [Prieto-Alvarez et al., 2018]. Generative design, on the other hand, is a process in which humans have tools to describe their needs and intentions, explore the design space, generate a set of target solutions, and then select and refine the most appropriate solution based on their own judgment [Keshavarzi et al., 2020].

Our work is aligned with the Co-design Model in Learning Analytics, as proposed by Prieto et al. [Prieto-Alvarez et al., 2018]. This model outlines a systematic approach to participatory design, which involves a series of iterative activities aimed at refining requirements and approaching the desired solution. In line with this model, our objective is to contribute tools and resources that specifically support the participatory design process for Learning Analytics Dashboards (LADs). By incorporating the principles of the Co-design Model, we aim to enhance the effectiveness and efficiency of the design process, ensuring that the resulting LADs are more user-centered, contextually relevant, and aligned with the needs of stakeholders.

In any design approach, it is important to clarify the roles of the actors involved. In the context of LADs, we can distinguish several roles that can be grouped into two key roles: (1) the *user* role (teachers, learners, administrators, etc.), referring to the actors expressing the needs and serving as end-users, and (2) the *developer* role, representing the actors responsible for specification, data and visualization design, user interface design, and LAD implementation.

2.2 Design Space

The concept of a *design space* [Shaw, 2012] identifies the different alternatives and structuring design decisions, providing relevant support for ideation, creation, and evaluation. In the case of LAD design, the 5 W's questions can be used to address such a design space [Chatti et al., 2020]. We formulate the 5 W's as follows:

- *Who?* indicates the audience and circulation among different users.

- *When?* addresses whether the usage is real-time or deferred.
- *Why?* translates the objective of the LAD in terms of decision-making.
- *What?* details the context of LAD usage and relevant data.
- *How?* relates to visualization and interactions.

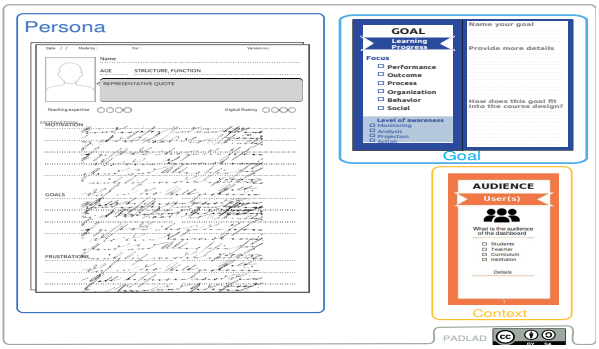
Table 1 summarizes the identified design dimensions and their respective values, which we have detailed in [Gilliot and Sadallah, 2023].

Tab. 1: Design Dimensions of LAD Design Space

Dimension	Elements	Values
Who?	User	Governance, Institution, Curriculum, Teacher/Tutor, Learner
	Circulation	Public, Organizational, Social, Individual
When?	Real-Time	Yes/No
Why?	Focus	Learning Process (Meta-)cognitive, Outcome or Process-oriented, Behavioral, Social
		Management (People, Resources, Activities, Experience)
	Level of Situational Awareness	Perception (or Monitoring), Understanding (or Analysis), Action (or Projection, Decision, Intervention)
What?	Data	List of relevant data
	Data Scope	Learner, Teacher, Class, Institution
	Data Source	Classroom, Learning Management Systems, Curriculum, Profile, Other
	Data Duration	One session, One semester, One year, Lifelong
How?	Visualization	Type of diagram
	Interaction	Zoom, Filter, Drill-down, Relationship, History, Extraction

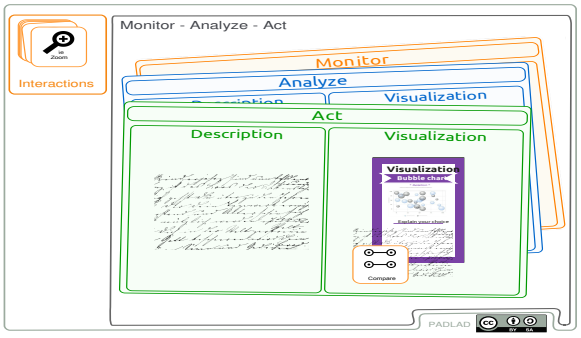
3 Participatory Design Tools

To support the participatory design process based on the proposed design space, we have developed two complementary tools: a collaborative ideation tool and a rapid prototyping tool. The user role is the target of the ideation tool, while the developer role, collaborating with the users, is the target of the prototyping tool.



(a) Identification Board

(b) DataViz Board



(c) Sketching Board

Fig. 1: PaDLAD Boards

3.1 Ideation Tool

The ideation phase is crucial as it involves the participation of stakeholders with diverse perspectives and knowledge to define the design goals early in the process. To support this phase, we have developed PaDLAD [Sadallah et al., 2022], an ideation toolkit that uses personas, exploration cards, boards, and sketching supports to encourage creativity and elucidate the different dimensions of the design space. The design process using PaDLAD consists of three phases represented by dedicated boards (Figure 1).

The *Identification Board* accommodates a *persona form*, a *goal form*, and a set of *context cards*. The *persona form* can be used to personify stakeholders and gather their information. The *goal form* establishes the problem that the dashboard aims to solve. This goal is defined based on the desired level of situational awareness (monitoring, analysis, action). The *context cards* describe the expected use of the dashboard: *Audience Cards* define the scope of analysis, *Data Cards* define the targeted data source and observation time.

The *DataViz Board* answers the question *What?* and includes a space reserved for tuples constructed from data and visualization cards. The *Data Cards* (or *Measure Cards*) identify the relevant data and indicators to achieve the dashboard's goal. The *Visualization Cards* are a set of technology cards proposing classic visualizations that are relevant to represent the information contained in the data cards.

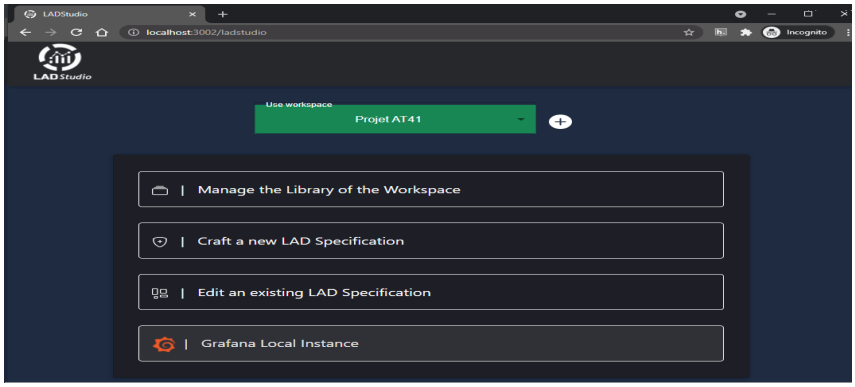
The *Sketching Board* aims to allow design actors to create views and graphical representations by sketching the targeted LAD and defining interaction options. We distinguish three types of views: (1) *Perception Views* allow monitoring the state of the environment; (2) *Understanding Views* include representations that provide the necessary insights to analyze and understand a given situation; and (3) *Projection Views* enable preparing the user to act on the situations discovered and analyzed in the previous levels.

3.2 Prototyping and Support Tool

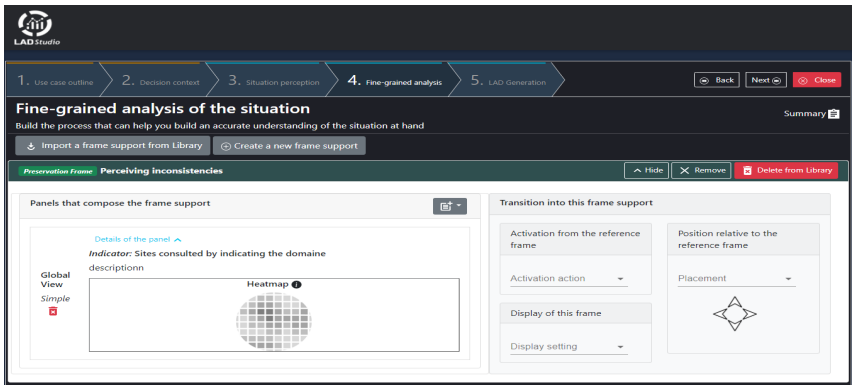
To support this phase, we have developed LADStudio [Sadallah and Gilliot, 2023], a tool that allows generating LAD prototypes through a declarative specification resulting from the ideation phase (Figure 2). It is provided as a web service integrating an instance of the Grafana visualization tool for rendering.

The specification module allows progressively describing a LAD (Figure 2b). This description can be a translation of the specifications made during the ideation phase (e.g., using PaDLAD). Sequential screens compose a scenario: (1) description of the target context and intended use; (2) definition of the main goal of the LAD; (3) description of the monitoring, understanding, and projection views; and (4) generation of a LAD specification that can be displayed on the Grafana module (Figure 2d). Such a specification can be edited again, enabling a cyclical process of editing and testing.

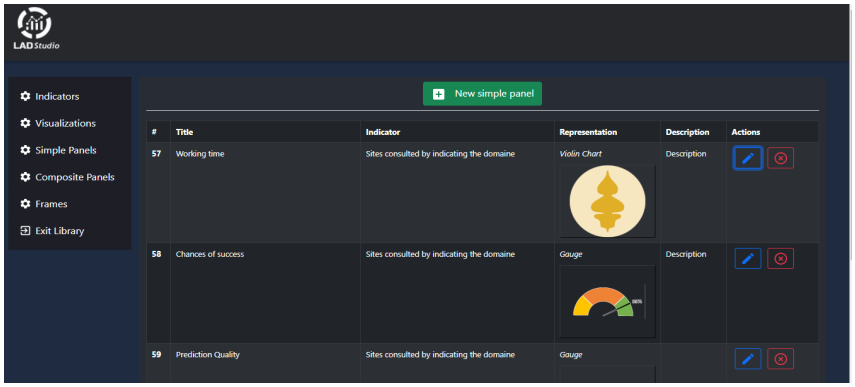
The components created during a specification are associated with interactions that support



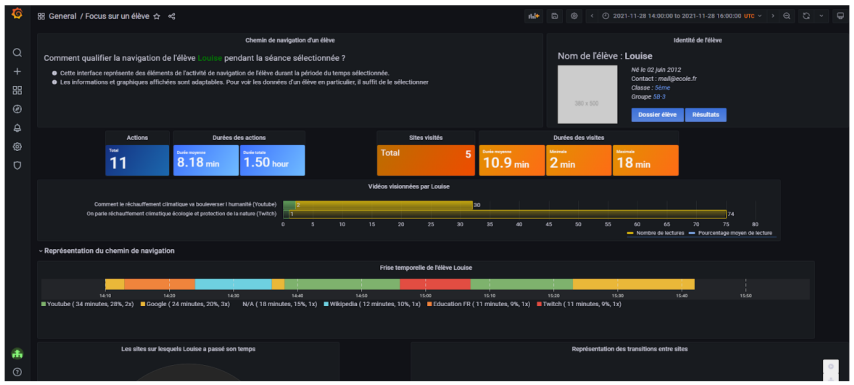
(a) LADStudio Home and Modules



(b) LAD Specification



(c) Board Library



(d) Generated LAD Prototype

Fig. 2: Some Elements of LADStudio

the sense-making process. They are automatically saved in a library, which simplifies the feeding of the library, allowing capitalization and reuse. The library can receive different types of components: indicators, visualizations, boards (Figure 2c), and views. It is extensible, allowing the definition of new components, modification of existing components, and deletion of components (in case of redundancy, for example).

4 Experiments

4.1 Problem Statement

We are interested in evaluating the proposed tools as support for participatory design of learning dashboards. Our research questions are as follows: *QR1*: Are the proposed tools usable by stakeholders for both the ideation phase and the specification and generation of learning dashboards?; *QR2*: Does the participatory design tool encourage collaboration and support participatory creativity within a group?; and *QR3*: Does the prototyping tool provide a good user experience?

4.2 Methodology

Two qualitative studies were conducted to evaluate the two tools. Fifteen participants took part in the PaDLAD study, which focused on the ideation phase and involved teachers, researchers, and instructional designers with no specific knowledge in Educational Technology. Thirteen participants participated in the LADStudio study, which focused on the prototyping phase and involved teachers, researchers, and instructional designers with technical knowledge in learning dashboards and Human-Computer Interaction (HCI) in the context of Educational Technology. Although LADStudio was intended for developers, participants with technical knowledge were recruited due to the difficulty of finding enough LAD developers to participate in the study. The socio-demographic data of the participants are presented in Table 2.

Tab. 2: Demographic data of participants in the two evaluations

Variable/Category		PaDLAD (N = 15)	LADStudio (N = 13)
Gender	Male	07	08
	Female	08	05
Age	30–45	11	07
	46–60	04	03
Profession	Teacher	06	04
	Instructional Designer	07	03
	Researcher	02	06

4.2.1 Procedure

To evaluate PaDLAD, we organized a participatory design workshop for LADs. After presenting the tool, the participants were divided into groups to create sketches of LADs. This session lasted approximately one and a half hours. The evaluation of LADStudio, conducted two months later, began with a demonstration session of the tool. Participants were then invited to individually experiment with the tool and participate in a LAD design workshop. The study lasted approximately two hours. At the end of each study, participants were individually asked to complete a questionnaire and respond to open-ended questions to gather their opinions.

4.2.2 Instruments

We evaluated the usability of the PaDLAD and LADStudio tools using the System Usability Scale (SUS) questionnaire [Brooke et al., 1996]. SUS is a valid instrument that provides an overall view of systems usability and is applicable even with a small sample [Tullis and Stetson, 2004]. Based on the general SUS model [Brooke et al., 1996], we prepared a questionnaire with ten statements for each study, each measured on a 5-point Likert scale (ranging from "Strongly Disagree" to "Strongly Agree").

To assess the extent of participant engagement in the ideation workshops, we employed the Self-Report Level of Participation Survey (SRLPS) questionnaire, as introduced by Hyett et al. [Hyett et al., 2020]. The SRLPS questionnaire is a well-established tool designed to measure the perceived level of engagement and active involvement of participants in collaborative design activities. This instrument focuses on five co-design activities: (1) Planning and organizing, (2) Creative design process, (3) Setting priorities, (4) Negotiation, and (5) Reflection and evaluation. Each participant was asked to evaluate their level of participation for each activity using the following scale: 1 = "Passive" (low-level participation), 2 = "Sharing of information," 3 = "Engagement and mobilization," 4 = "Collaboration," and 5 = "Empowerment" (high-level participation). The aim was to achieve a median of 4 (collaboration) for each activity.

The evaluation of the user experience (UX) of LADStudio was conducted using the User Experience Questionnaire (UEQ), a valid instrument for comprehensive measurement of the UX of interactive products [Laugwitz et al., 2008] and applicable to small groups [Schrepp et al., 2014]. The questionnaire consists of 26 items divided into six scales [Santoso et al., 2016]. These scales assess the overall impression of the tool (Attractiveness), its ease of use and efficiency (Efficiency and Comprehensibility scales), the user's sense of control (Controllability), its excitement and motivation (Stimulation), and the originality and creativity of the tool's design (Novelty).

5 Results

5.1 Usability of the Tools

To analyze the results, we calculated the normalized SUS scores (values between 0 and 100). The evaluation results from the participants of both tools are presented in Figure 3. The average SUS score for PaDLAD was 73.5 (standard deviation of 9.34), and for LADStudio it was 71.15 (standard deviation of 6.15). Since a SUS score is considered acceptable if it is above 68 [Brooke et al., 1996], we can state that both tools achieve a satisfactory and acceptable level of usability.

The SUS scores can be associated with an adjective scale of acceptability, as proposed in [Bangor et al., 2009], to provide a more descriptive meaning. Using this scale, as shown in Figure 3, the SUS scores assigned to these tools signify that their *degree of acceptability* is at an *Acceptable* level, and their grading level is in the *Good* category.

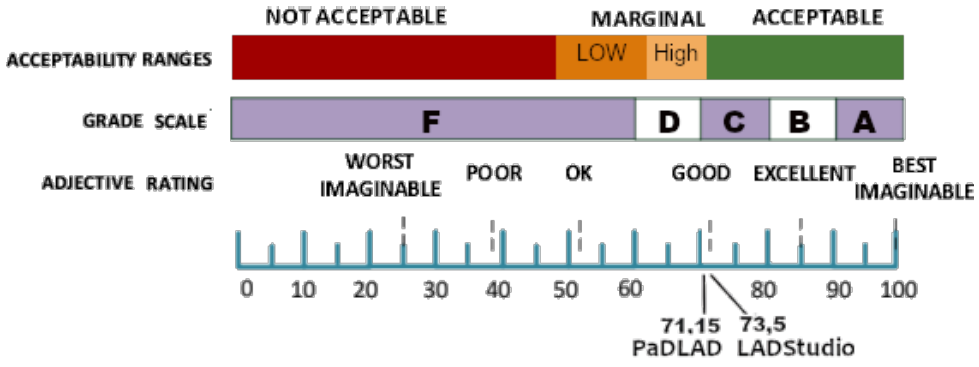


Fig. 3: Results of the usability evaluation of PaDLAD and LADStudio.

5.2 Quality of Participation in PaDLAD

The values obtained from the SRLPS questionnaire for the measured activities are displayed in Table 3. The target score of collaboration (median of 4) was achieved for all activities, with very little variability in scores between participants. Elements related to conducting activities as part of the creative design process and negotiating design choices received the highest level of participation (mean of 3.66 and 3.60, respectively). Despite a good score, the element related to setting priorities still obtained the lowest level of participation (mean = 3.20).

It is interesting to note that while none of the participants rated their participation as passive on any of the evaluated items, none of them also indicated the highest level of participation on any of the items. This can be explained by the novelty of the experience, as well as the fact that participants feel ill-equipped in terms of background and experience to be prepared to design tools themselves that they have only previously used in an incidental way.

Tab. 3: Results of the quality of participation study for PaDLAD

Main Activity	Mean (Standard Deviation)	Median (Min-Max)
Planning and organizing	3.46 (0.64)	4 (2-4)
Creative design process	3.66 (0.62)	4 (2-4)
Setting priorities	3.20 (0.94)	4 (2-4)
Negotiation	3.60 (0.82)	4 (2-5)
Reflection and evaluation	3.40 (0.74)	4 (2-4)

Scales: 1 = Passive, 2 = Sharing of Information, 3 = Engagement and Mobilization, 4 = Collaboration, and 5 = Empowerment.

5.3 User Experience of LADStudio

We calculated the results of the UEQ following the procedure proposed by its creators after scaling the participants' responses from -3 (extremely negative) to +3 (extremely positive) on a Likert scale. Scores between -0.8 and 0.8 reflect a neutral evaluation, scores above 0.8 indicate a positive evaluation, and scores below 0.8 imply a negative evaluation.

The scores obtained for LADStudio are sufficiently high (Figure 4). The scores for the dimensions *Novelty*, *Efficiency*, and *Stimulation* are at an excellent level. The highest score is for the *Novelty* dimension, with an average of 2.48, followed by the *Efficiency* dimension (average = 2.27) and the *Stimulation* dimension (average = 2.25). These scores are at an excellent level. The *Controllability* dimension has a good score (average = 1.64). The *Comprehensibility* dimension had the lowest result (average = 1.13), indicating that participants experienced some difficulties in understanding the use of the tool.

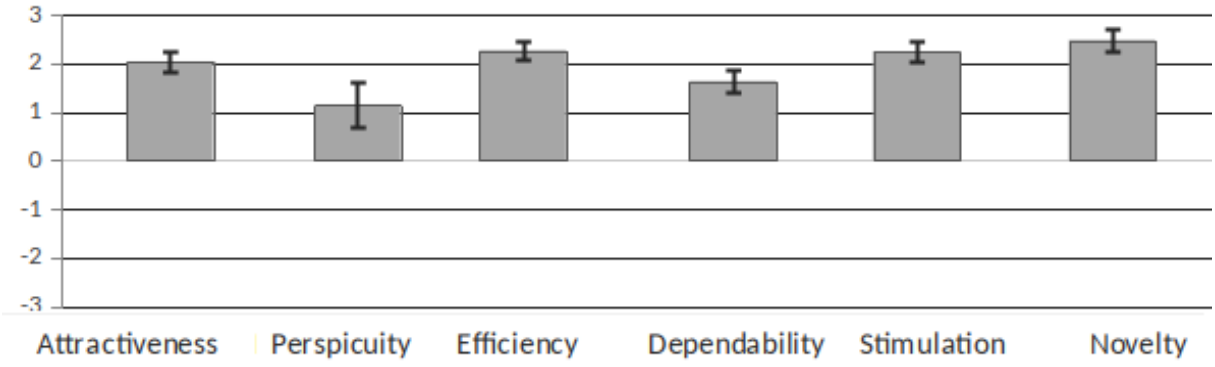


Fig. 4: Results of the user experience evaluation of LADStudio.

5.4 Participant Comments

Participants felt that the ideation phase tool, PaDLAD, brought out original design ideas, particularly through the dynamics of exchange and sharing. It also overcomes the challenge of designing LADs with limited knowledge of data and visualization. The construction of views based on levels of awareness reflects the steps of reasoning and allows for projection

into real usage scenarios, as one participant stated: "What is interesting is the emphasis on the story you want to tell through the maps, which is a very interesting and even innovative perspective." Another participant also raised the challenges of building panels associated with different levels of situational awareness: "The possibility of projecting the reasoning process into visual representations is appealing, although it adds complexity to having to determine the different steps and build the corresponding screens. Additionally, sometimes a single screen is sufficient for all steps."

Regarding the comments related to LADStudio, participants found the tool to be very useful in clarifying expectations and materializing responses, as one participant highlighted: "Such a tool allows us not to remain at the ideas and sketches level but to continue working on functional prototypes." However, its use requires understanding the context and rationale behind it. Participants were able to use it correctly with practice. They also appreciated the emphasis on designing LADs that support the user's sense-making process, but, similar to PaDLAD, they found that integrating theoretical concepts related to the decision-making process could make the initial adoption of the tool challenging.

6 Discussion & Conclusion

Participatory design enables the creation of products that are both useful and usable by users because they align with their expectations. In this contribution, we have proposed to provide tools for participatory design of LADs to help address their relatively limited adoption. The results of the evaluated aspects show that participants did not encounter difficulties in using the tools, demonstrating a positive attitude towards the appeal and usability of these tools, which is very encouraging for the future development of PaDLAD and LADStudio and addresses our research question *QR1*.

The SRLPS study demonstrated the capabilities of PaDLAD to create an environment that encourages communication, exchange, and creativity among participants (addressing *QR2*). Finally, the user experience offered by LADStudio is overall at an acceptable level and notably shows that participants perceive the tool as highly creative, efficient, and stimulating, allowing us to positively answer the addressed research question *QR3*.

Despite promising results, this study has some limitations. Firstly, given the qualitative nature of this research, self-selection biases may have been introduced as only participants with an interest in LADs responded to our invitations. As indicated by the participants, the adoption of LADs and more generally LA tools was still in its early stages, and their implementation, both by the participants and their institutions, was often of limited scope.

Additionally, the study can only provide an indication of the quality of the tools due to the limited number of participants. To ensure the validity of the conclusions, a larger-scale evaluation needs to be conducted. Research has shown that the use of SUS provides a reliable measure of perceived usability of a system, even with a relatively small sample size

[Tullis and Stetson, 2004]. In [Nielsen, 2000], five users are deemed sufficient for a reliable usability test. Furthermore, the UEQ has been shown to be applicable even with a limited group of participants [Schrepp et al., 2014]. However, to ensure the validity of the results, a more in-depth survey involving a larger number of participants would be necessary. Additionally, a large-scale longitudinal study would be essential to assess the quality of the created LADs and the impact of using these tools, focusing on the perspective of instructional design.

Our studies have provided compelling evidence of the innovation inherent in the proposed approach and the developed tools, as they effectively address two prominent challenges that impede the widespread adoption of Learning Analytics Dashboards (LADs): the lack of end-user involvement and the technical complexities associated with creating LADs from scratch. By actively involving stakeholders in a supportive and assistive environment, our approach fosters a collaborative design process that yields innovative solutions for LAD adoption.

The successful implementation of our approach raises intriguing research questions regarding the instrumentation of LAD design. For instance, the issue of *transferability* emerges as a critical challenge, as it pertains to the adaptability and effectiveness of LADs across diverse usage contexts. Exploring the transferability of LADs between different educational settings and user groups is vital to ensure the usability and utility of these dashboards for a wider audience.

Additionally, investigating the invariants among proposals from various user groups poses an important research challenge. Understanding the commonalities and differences in LAD requirements and preferences across different user categories can inform the development of adaptable and customizable LAD frameworks. By identifying the core elements that resonate with diverse stakeholders, we can design LADs that cater to their specific needs while maintaining a consistent foundation.

Overall, the results obtained from our studies and the emerging research questions emphasize the potential for continued advancements in LAD design and adoption. By addressing the challenges of stakeholder involvement and technical complexity, we lay the foundation for future innovations and improvements in the field of Learning Analytics.

References

[Alhamadi, 2020] Alhamadi, M. (2020). Challenges, strategies and adaptations on interactive dashboards. In *Proceedings of the 28th ACM Conference on User Modeling, Adaptation and Personalization*, pages 368–371.

[Alvarez et al., 2020] Alvarez, C. P., Martinez-Maldonado, R., and Shum, S. B. (2020). La-deck: A card-based learning analytics co-design tool. In *Proceedings of the tenth international conference on learning analytics & knowledge*, pages 63–72.

[Bangor et al., 2009] Bangor, A., Kortum, P., and Miller, J. (2009). Determining what individual sus scores mean: Adding an adjective rating scale. *Journal of usability studies*, 4(3):114–123.

[Brooke et al., 1996] Brooke, J. et al. (1996). Sus-a quick and dirty usability scale. *Usability evaluation in industry*, 189(194):4–7.

[Chatti et al., 2020] Chatti, M. A., Muslim, A., Guliani, M., and Guesmi, M. (2020). The lava model: Learning analytics meets visual analytics. In *Adoption of data analytics in higher education learning and teaching*, pages 71–93. Springer.

[Dollinger et al., 2019] Dollinger, M., Liu, D., Arthars, N., and Lodge, J. M. (2019). Working together in learning analytics towards the co-creation of value. *Journal of Learning Analytics*, 6(2):10–26.

[Echeverria et al., 2018] Echeverria, V., Martinez-Maldonado, R., Granda, R., Chiluiza, K., Conati, C., and Shum, S. B. (2018). Driving data storytelling from learning design. In *Proceedings of the 8th International Conference on Learning Analytics & Knowledge*, pages 131–140. ACM.

[Gilliot et al., 2018] Gilliot, J.-M., Iksal, S., Medou, D. M., and Dabbebi, I. (2018). Conception participative de tableaux de bord d'apprentissage. In *IHM'18: 30e Conférence Francophone sur l'Interaction Homme-Machine*, pages pp–119.

[Gilliot and Sadallah, 2023] Gilliot, J.-M. and Sadallah, M. (2023). A framework for co-designing effective lads supporting sensemaking and decision making. *International Journal of Learning Technology*. (in press).

[Hyett et al., 2020] Hyett, N., Bagley, K., Iacono, T., McKinstry, C., Spong, J., and Landry, O. (2020). Evaluation of a codesign method used to support the inclusion of children with disability in mainstream schools. *International Journal of Qualitative Methods*, 19:1–12.

[Keshavarzi et al., 2020] Keshavarzi, M., Bidgoli, A., and Kellner, H. (2020). V-dream: Immersive exploration of generative design solution space. In *International Conference on Human-Computer Interaction*, pages 477–494.

[Laugwitz et al., 2008] Laugwitz, B., Held, T., and Schrepp, M. (2008). Construction and evaluation of a user experience questionnaire. In *Symposium of the Austrian HCI and usability engineering group*, pages 63–76. Springer.

[Nielsen, 2000] Nielsen, J. (2000). Why you only need to test with 5 users.

[Prieto-Alvarez et al., 2018] Prieto-Alvarez, C. G., Martinez-Maldonado, R., and Anderson, T. D. (2018). Co-designing learning analytics tools with learners. In *Learning Analytics in the Classroom*, pages 93–110. Routledge.

[Sadallah et al., 2015] Sadallah, M., Encelle, B., Maredj, A.-E., and Prié, Y. (2015). Towards reading session-based indicators in educational reading analytics. In *Design for Teaching and Learning in a Networked World: 10th European Conference on Technology Enhanced Learning, EC-TEL 2015, Toledo, Spain, September 15-18, 2015, Proceedings 10*, pages 297–310. Springer.

[Sadallah et al., 2020] Sadallah, M., Encelle, B., Maredj, A.-E., and Prié, Y. (2020). Towards fine-grained reading dashboards for online course revision. *Educational Technology Research and Development*, 68:3165–3186.

[Sadallah and Gilliot, 2023] Sadallah, M. and Gilliot, J.-M. (2023). Generating lads that make sense. In *Proceedings of the 15th International Conference on Computer Supported Education - Volume 1: CSEDU 2023*, pages 35–46. INSTICC, SciTePress.

[Sadallah et al., 2022] Sadallah, M., Gilliot, J.-M., Iksal, S., Quelennec, K., Vermeulen, M., Neyssensas, L., Aubert, O., and Venant, R. (2022). Designing lads that promote sensemaking: A participatory tool. In Hilliger, I., Muñoz-Merino, P. J., De Laet, T., Ortega-Arranz, A., and Farrell, T., editors, *Educating for a New Future: Making Sense of Technology-Enhanced Learning Adoption*, pages 587–593, Cham. Springer International Publishing.

[Santoso et al., 2016] Santoso, H. B., Schrepp, M., Isal, R., Utomo, A. Y., and Priyogi, B. (2016). Measuring user experience of the student-centered e-learning environment. *Journal of Educators Online*, 13(1):58–79.

[Sarmiento and Wise, 2022] Sarmiento, J. P. and Wise, A. F. (2022). Participatory and co-design of learning analytics: An initial review of the literature. In *Proceedings of the 12th International Learning Analytics and Knowledge Conference*, pages 535–541.

[Schrepp et al., 2014] Schrepp, M., Hinderks, A., and Thomaschewski, J. (2014). Applying the user experience questionnaire (ueq) in different evaluation scenarios. In *International Conference of Design, User Experience, and Usability*, pages 383–392. Springer.

[Schwendimann et al., 2017] Schwendimann, B. A., Rodríguez-Triana, M. J., Vozniuk, A., Prieto, L. P., Boroujeni, M. S., Holzer, A., Gillet, D., and Dillenbourg, P. (2017). Perceiving learning at a glance: A systematic literature review of learning dashboard research. *IEEE Transactions on Learning Technologies*, 10(1):30–41.

[Shaw, 2012] Shaw, M. (2012). The role of design spaces. *IEEE software*, 29(1):46–50.

[Tullis and Stetson, 2004] Tullis, T. S. and Stetson, J. N. (2004). A comparison of questionnaires for assessing website usability. In *Usability Professionals Association (UPA) 2004 Conference*.

[Wang and Hannafin, 2005] Wang, F. and Hannafin, M. J. (2005). Design-based research and technology-enhanced learning environments. *Educational Technology Research and Development*, 53(4):5–23.