Learner Experience in Technology-Enhanced Education: A Conceptual Framework of Design and Evaluation

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Abstract. *Learner Experience (LX) refers to learners' perceptions and responses when interacting with educational activities supported by computational resources. The problem is that LX elements are often addressed implicitly, creating misalignment between planned activities and learners's actual experiences. Thus, the goal of this thesis was to develop the LEDEF framework. The methodology was grounded in the Design Science Research paradigm and involved systematic mapping studies, feasibility studies, and case studies. The main results include 12 publications and the development of three technologies aimed at supporting educators, designers, and researchers. This research advances the continuous improvement of LX.*

1. Introduction

The concept of Learner eXperience (LX) can be understood as learners' perceptions and responses when participating in activities supported by computational resources, extending the concept of User Experience (UX) to the educational context [Huang et al. 2019]. The literature defines UX as the preferences, perceptions, emotions, and physical and psychological responses of the user that occur before, during, and after use [Bevan et al. 2016]. Thus, LX and UX are concepts related, both addressing the quality of the experience an individual has when interacting with computational resources.

LX resembles UX in that it involves cognitive processing and subsequent responses [Huang et al. 2015]. This parallel is particularly evident when the experience focuses on learners' interactions with educational resources. On the other hand, Learning Design (LD) also shares similarities with LX, placing educational experiences at the center of the learning process [Miller 2014]. Just as UX is relevant for the success and acceptance of software, LD contributes to the design of learning by providing insights into learners' needs and experiences, fostering the creation of engaging and meaningful educational activities [Huang et al. 2019]. Therefore, LX can be seen as the intersection of LD, UX, and educational technology [Schmidt and Huang 2022].

Similar to UX, LX encompasses elements that guide both the design and evaluation of learning experiences, enabling the inclusion and verification of experience-related characteristics, such as feelings and emotions in learning. Within the stages of the LX life cycle, particular emphasis has been placed on the design and evaluation phases, which are considered the most critical because of their direct impact on the quality of the educational

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experience. For example, Arachchi et al. (2017) demonstrated that design can positively affect usability, accessibility, and learning, LX elements that shape educational experiences. Furthermore, Magyar and Haley (2020) showed that evaluation helps identify and correct LX design problems, preventing them from negatively affecting learners.

Based on the scientific literature, we found that LX technologies (both in terms of design and evaluation) present a variety of approaches to addressing LX, employing specific techniques, processes, and methods [Silva and Valentim 2023]. However, a key limitation is that these technologies often focus on a limited set of LX elements and do so implicitly, which contrasts with the recommendation by Huang et al. (2019) to adopt a comprehensive perspective. This pluralistic perspective seeks to consider the diversity of learners and their preferences, enabling a more complete understanding of the educational experience involving computational resources.

Treating LX design and evaluation in isolation can lead to misalignment between design dimensions and actual learning outcomes [Martin et al. 2017], creating gaps between planned activities and learners' experiences. Moreover, separating design from evaluation hinders the identification of improvements. While LX evaluation is essential for identifying strengths and areas for improvement in the learner experience [El Mawas et al. 2020], without a direct connection to the design process, it becomes difficult to gather in-depth feedback on the effectiveness of computational resources and learners' needs during educational activities [Papavlasopoulou et al. 2019].

From this perspective, we proposed the Learner Experience Design and Evaluation conceptual Framework (LEDEF), using the Design Science Research (DSR) paradigm. According to Pawson and Tilley (1997), a conceptual framework serves as a guide for action, directing decision-making and the implementation of interventions in various contexts. It provides principles and guidelines for professional practice, promoting coherence and effectiveness in actions. LEDEF is composed of two technologies, one entitled Learner Experience Design Guidelines (LEDG) and the other Learner Experience Evaluation Model (LEEM). The research question of this research was: "How can LX be designed and evaluated by considering appropriate elements and technologies to support educational experiences involving computational resources?". To evaluate LX using LEDEF, we conducted a case and feasibility studies.

This research contributes to the field of Informatics in Education by analyzing an educational activity through the lens of Dewey's (1938) perspective on the nature of human experience, recognizing that LX involves not only cognitive processes but also an emotional and sensory journey that transforms both the individual and their context. A key contribution of this thesis is the application of our conceptual framework, LEDEF, which explicitly addresses elements of LX and provides a structured process for designing, evaluating, and refining educational activities. LEDEF offers teachers greater flexibility in selecting LX components while providing a well-defined workflow with steps, goals, and artifacts that can be adapted to diverse educational contexts.

This doctoral research resulted in 12 publications in conferences and journals, including Informatics in Education (INFEDU), the Journal of the Brazilian Computer Society (JBCS), the Brazilian Symposium on Computers in Education (SBIE), and the Best Paper Award in the track on innovative ideas and emerging results at the Brazilian Symposium on Human Factors in Computing Systems (IHC), among others. It also led to the development of three technologies (freely available online) that can be used independently or in combination. Furthermore, this work directly supported two master's thesis focused on the evaluation and enhancement of LX.

2. Related Work

Despite the importance of discussing LX, finding works that provide clear concepts and definitions on the topic, along with well-defined elements to be explored, remains a challenge. Thus, three studies were selected for the following reasons: they (a) address LX design or evaluation; (b) present an approach oriented toward LX elements; and (c) focus on use computational resources.

Ortiz et al. (2019) conducted activities with 12 learners in the Youth and Adult Education (EJA) program, aged between 21 and 70, aimed at removing barriers to using WhatsApp. The methodology involved practical activities using resources such as cards with facial expressions, research, and qualitative observations to capture participants' perceptions, emotions, and engagement levels. The results indicate that contextualized, playful, and visually accessible activities foster positive feelings of satisfaction, autonomy, and belonging. Notably, this study highlights LX in a socially vulnerable context, as adult learners often face digital exclusion and limited prior access to technology.

Silva et al. (2020) conducted a study with 25 elementary school students, divided into five groups of five, covering grades 4th to 9th, to analyze LX in Unplugged Computing activities in riverside schools in the Tapajós-Arapiuns region of Pará, Brazil. A qualitative approach was adopted, including focus group. The results indicated that students perceived the activities positively, fostering feelings of enjoyment, autonomy, collaboration, and motivation. This work also addresses digital vulnerability, as these schools have low infrastructure and limited access to computational resources, highlighting how context-aware and low-cost interventions can support inclusive learning experiences.

Zhang et al. (2018) introduced a cross-stitch experiential learning model with rural children. The LX included four distinct stages: (1) Introduction; (2) Distribution of cross-stitch materials; (3) Practical demonstration of skills; and (4) Practice time for learners. Learners were also invited to self-assess at each stage of the activity, rating Affinity, Challenge, and Frustration aspects with up to 5 stars. A study was conducted, dividing learners into two groups, both composed of one teacher, one observer, and five learners. One group underwent the traditional cross-stitch method, while the other used a digital game. The results revealed differences between the two groups, with Group B demonstrating greater interest and engagement due to the use of the digital game, which also served as a tool to address difficulties and as a reference for learners.

Based on these studies, gaps are highlighted. Ortiz et al. (2019) focus on the flexibility of activities; however, their approach does not allow teachers to monitor and adjust their actions over time. Furthermore, Silva et al. (2020) primarily employ qualitative methodologies based on participant narratives, which may limit the objectivity in assessing the impact of the activities and do not allow for a longitudinal evaluation of learners' experiences. Zhang et al. (2018) emphasize the significance of collaborating with more experienced participants, highlighting that inviting skilled people could facilitate the identification of issues and aid struggling learners.

Our framework, LEDEF, not only explicitly addresses key elements of the LX, but also provides a set of LX elements, giving teachers greater flexibility in selecting which components to include in their activities. It offers a well-structured process with steps, goals, and artifacts that can be tailored to specific contexts and needs, allowing teachers to have a guided and organized path throughout the learning journey. LEDEF supports teachers to create, evaluate and adjust their activities using computational resources to meet the unique needs of their classes, while also enabling them to evaluate and refine the LX from multiple perspectives throughout its lifecycle. As no existing technology in the literature was found to encompass these characteristics, the LEDEF conceptual framework was proposed to fill this gap.

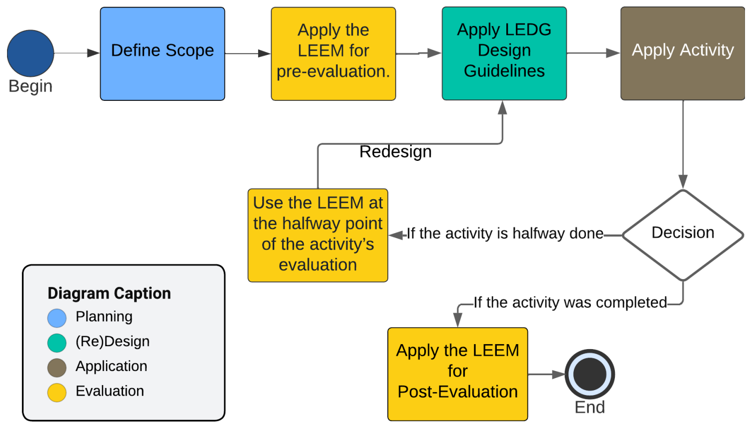
3. LEDEF Conceptual Framework

LEDEF is composed of two LX technologies, the LEDG and the LEEM (available in Appendices A and B). It provides a complete cycle of LX, allowing visualization of both what is proposed activity and what is actually experienced by learners, experiences that can directly impact the learning process. The LEDEF can help identify strengths and areas for improvement related to LX, enabling the redesign of activities using computational resources. As it deals with educational experiences, LEDEF can be used by all those interested in LX, such as educators, instructional designers, and developers of educational resources and materials. The LEDEF meet the following requirements: (1) Applicable to Higher Education: because the use of resources requires a certain level of learner maturity. Furthermore, the framework was developed and validated through studies conducted in this context [Silva et al. 2024a] [dos Santos et al. 2022]; (2) Possibility of Choosing LX Elements: A set of elements is provided that have been mapped and related so that the teacher can select and work on the design and evaluation of LX, with a focus on elements of LX, such as Value, Usability, Adaptability, Desirability, and Comfortability; and (3) Possibility of Choosing Computational Resources: A set of 75 tools has been compiled and categorized for use in educational experiences, as recommended by the guidelines.

It is worth noting that the technologies comprising the LEDEF can be used independently. Thus, a teacher interested in evaluating LX in their educational activities may choose to use only the LEEM. However, if the goal is also to create activities based on LX, the LEDG can be used to guide the design. Figure 1 illustrates LEDEF, considering an educational activity from beginning, where the teacher navigates and makes decisions, incorporating computational resources into their activity to provide an engaging LX. LEDEF consists of four stages (planning, design, application, and evaluation), organized into nine activities presented below.

In LEDEF, the teacher begins by defining the scope of the educational activity, including the course focus, class schedule, content, participating students, and the learning environment. o better understand learners' difficulties and preferences, the teacher administers the LEEM pre-evaluation questionnaire. Based on this data, the teacher selects appropriate LEDG guidelines [Silva et al. 2024b] to plan the activity, choose computational resources, and prepare support materials. The activity is then implemented in the classroom, with learners actively engaging in the proposed tasks. LEDEF reserves a specific moment for LX, during which learners can actively participate and have learning experiences. When learners reach 50% of the proposed activity, the instructor conducts the mid-activity evaluation using LeXEM to monitor progress, identify any difficulties

Figure 1. LEDEF Conceptual Framework.



related to the activity, and use the evaluation checklist to document these experiences. If necessary, the teacher can redesign their activities to seek a more satisfactory LX in the remaining 50% of the activity. LEDEF concludes with the post-evaluation using LEEM, in which learners reflect on and share their educational experiences, participating in activities with computational resources.

LEDEF seeks to be flexible regarding this set of artifacts. Thus, the following conditions are presented: if the teacher already has the activity ready, they can use only the post-evaluation of LEEM to collect educational experiences; if the teacher already has the activity defined but does not consider it satisfactory, they can administer the during evaluation of LEEM and the guidelines of LEDG to redesign it; if they wish to make a preliminary adaptation to their activity before presenting it to the learners, they can apply only the pre-evaluation and the guidelines of LEDG; finally, if the teacher already has a ready LX evaluation process, they can use only the guidelines of LEDG to define the activity, the computational resource, and the support materials. In summary, LEDEF seeks to offer the teacher options to adapt the activity according to the needs of the learners and educational situations. Additionally, it allows for the inclusion of new guidelines and technologies throughout the educational activity.

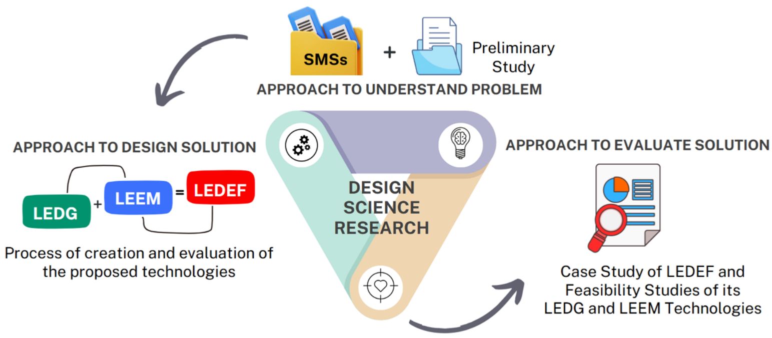
4. Method

This research was conducted based on DSR. Figure 2 outlines the research scope and process, which comprises three parts. Phase 1 shows the approach to understanding the problem, including the results from the SMSs, as well as the preliminary study. In Phase 2, the approach to designing the solution is presented. Finally, Phase 3 involves the approach to evaluating the solution, which includes the LEDEF feasibility study and the case study.

4.1. Data Collection Methods

In this research, different instruments were prepared and used for data collection. First, the Informed Consent Form (ICF) was employed to ensure participants' understanding and voluntary participation in the study. Next, a participant characterization questionnaire was administered to gather relevant demographic and contextual information for data analysis. Specific instruments were developed, including a presentation of the technology being evaluated and a suggested activity for its use. Technology Acceptance ques-

Figure 2. Research Visual Abstract.



tionnaires (TAM3) were also utilized to investigate participants' perceptions of Ease of Use, Perceived Usefulness, and Future Use Intention.

In some cases, semi-structured interview scripts were developed, which provided a deeper understanding of participants' experiences and opinions. A request form for the use of image and/or voice for research purposes was prepared, ensuring participants' authorization for audiovisual recording during the interview process. These instruments were carefully selected and developed to meet the specific objectives of the research and ensure the quality and ethics of data collection. The study was approved by the Research Ethics Committee of UFPR under the Certificate of Presentation for Ethical Consideration (CAAE): 77365824.4.0000.0102 (LEDG feasibility study), 64733822.0.0000.0102 (LEEM feasibility study), 67603723.9.0000.0102 (LEEM case study), 77365824.4.3001.9247 (LEDEF case study).

4.2. Data Analysis Methods

The collected data were analyzed quantitatively and qualitatively. For the quantitative data, descriptive statistics were used. For questionnaires that utilized indicators from the TAM3, participants' responses on the agreement scale (strongly agree, partially agree, neither agree nor disagree, partially disagree, and strongly disagree) were obtained.

The original sentences for each indicator were adapted to reflect the specific research context and were peer-reviewed in collaboration with the research advisor. The goal was to focus on aspects directly relevant to evaluating the proposal. The use of TAM3 was based on its validation in various previous experiments [Venkatesh and Bala 2008]. For quantitative analysis, the Microsoft Excel[1] spreadsheet tool was used.

Qualitative data were analyzed using thematic analysis [Braun and Clarke 2006] with Atlas.ti[2], which allowed for the identification of emerging patterns and themes in the data. The analysis process included steps such as familiarizing with the data, generating initial codes, identifying potential categories, and refining these categories.

5. Results and Discussion

Approach to Understand Problem: A first SMS was conducted, focusing on identifying technologies that support the design of LX mediated by computational resources

[1] `https://www.microsoft.com/pt-br/microsoft-365/excel`
[2] `https://atlasti.com/pt`

[Silva et al. 2024a]. The results revealed a wide variety of approaches and tools, with the Approach category being the most recurrent among the identified technologies. A trend was also observed in the use of computational resources integrated into sequences of steps or activities, promoting learner engagement. The Value element was highlighted as central to LX design, given its strong relationship with learning effectiveness. The analysis showed that the strategic combination of multiple elements can enrich the LX.

The second SMS aimed to identify strategies and technologies for LX evaluation [dos Santos et al. 2022]. Thirty-two distinct evaluation approaches were found, with "Items/Sentences" being the most frequently used form. The analysis allowed for mapping 54 different elements that are targets of evaluation in the reviewed publications. However, it was observed that these elements are generally used in isolation, with Value, Usability, and Adaptability being prominent. This fragmentation highlights a gap in the literature: the absence of integrated evaluative approaches that simultaneously consider multiple LX elements within a single methodological structure. In response to this gap, the LEEM evaluation model was proposed, aiming to unify these elements and incorporate multiple forms of evaluation into a cohesive structure.

The complete protocol, including selection criteria, other strategies, and data extractions, is available in the technical reports in Appendices C and D. Based on the results obtained from the SMSs, several directions for future research emerge. One is the deepening of collaborative LX, considering interactions among different stakeholders (such as peers, teachers, parents, and industry professionals) with a view to expanding social interaction dynamics. Another possibility is to investigate why LX design has predominantly focused on basic education, while evaluation studies have mainly targeted higher education. Finally, the need to explore LX in more dynamic and immersive educational contexts, such as environments with extended reality and ubiquitous, pervasive, or virtual platform learning, is highlighted.

Additionally, a preliminary study was conducted with 36 students from an experimental HCI course, aiming to explore, in a real classroom context, the constitutive elements of LX [Silva et al. 2022]. This practical experience led to the formulation of 16 initial guidelines organized based on the LX elements: Value, Usability, Desirability, Adaptability, and Comfortability [Silva et al. 2023]. These guidelines provided pedagogical support for promoting interaction in learner-centered experiences using computational resources, in addition to contributing to decisions and lessons learned throughout the study. Such preliminary guidelines, combined with those identified in the SMS on design, underpinned the final proposal of the LEDG [Silva et al. 2024b]. These guidelines were conceived to articulate with the LEEM evaluation model (created from the second SMS), jointly forming the LEDEF framework, which integrates both design and evaluation aspects of LX in the use of computational resources.

Approach to Design Solution: The first version of the guidelines LEDEF contained 35 guidelines. After a peer-review process conducted by the research supervisors, specialists in Informatics in Education, Human-Computer Interaction and Software Engineering, two guidelines were excluded, and 11 were integrated into others, resulting in the 22 guidelines (Table 1) of the current version. The removed guidelines “Propose activities with computational resources” and “Allow learners to interact with new computational resources” were considered redundant, as the use of computational resources is already transversally encouraged in the other guidelines.

In grouping the guidelines, the aim was to consolidate those with similar objectives. For instance, guidelines on diagnostic assessment and feedback were unified in G6, which covers learner feedback before, during, and after the activity. G20 resulted from the fusion of guidelines addressing the practical application of content and the presentation of challenges. G12 brought together guidance on thematic organization, emerging topics, and division into smaller parts. Similarly, guidelines related to the presence of tutors and continuous support now constitute G22.

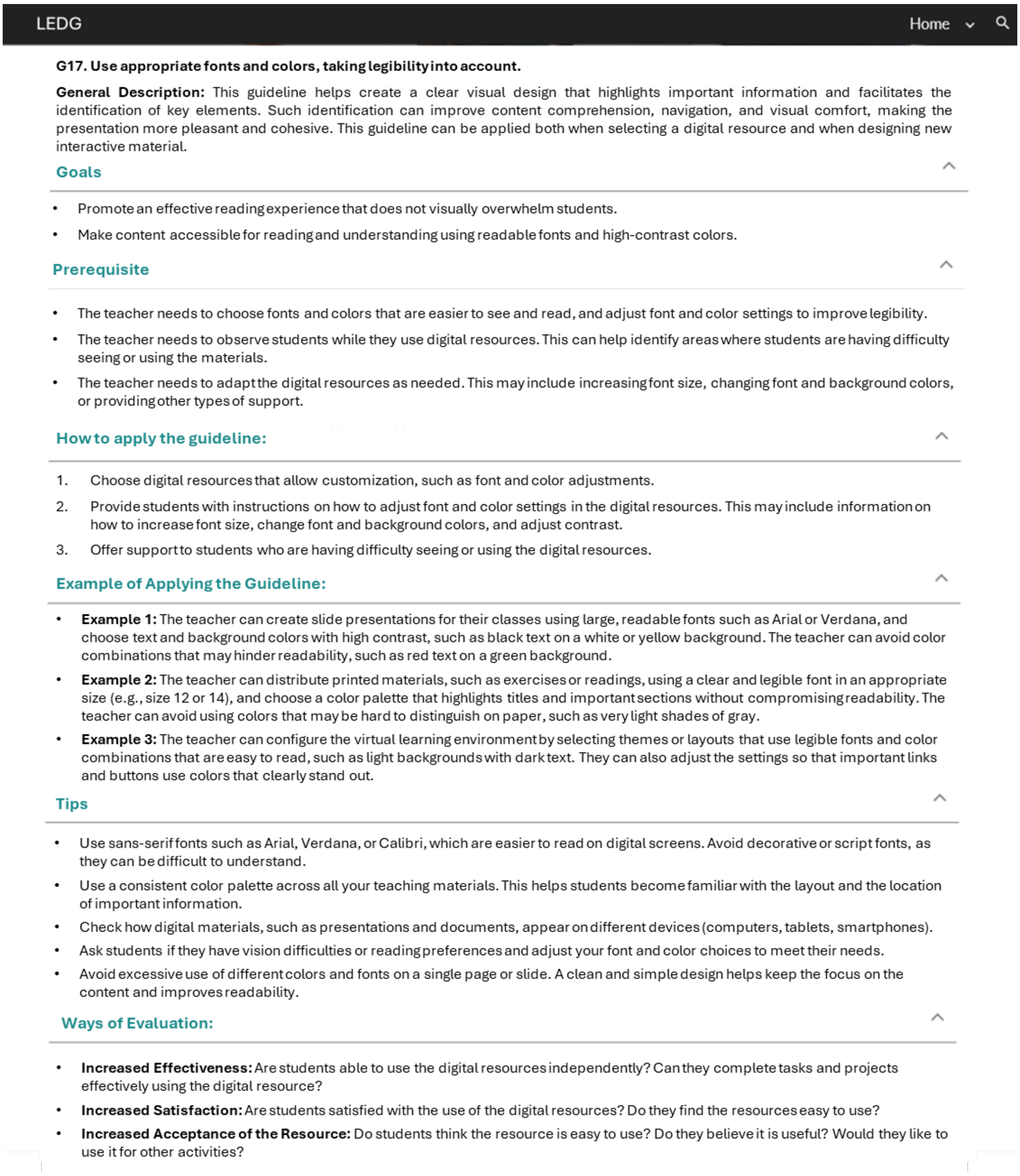
Table 1. List of LEDG Design Guidelines.

Qty.	List of Guidelines (G)
G1.	Foster learners' responsibility
G2.	Anticipate materials for learners' preparation
G3.	Allow learners to choose an appropriate space and time
G4.	Allow personalized access to materials
G5.	Allow learners to express themselves and ask questions
G6.	Request continuous feedback from learners
G7.	Explain content with visual and multimedia support
G8.	Provide guidance and tips to support learners
G9.	Allow learners to make choices
G10.	Connect content to prior knowledge
G11.	Present content clearly and concisely
G12.	Organize content by themes or topics
G13.	Allow learners to break down problems into smaller steps
G14.	Offer visible and challenging support
G15.	Use appropriate icons and menus
G16.	Use consistent layout positioning
G17.	Use appropriate fonts and colors
G18.	Use familiar and recognizable symbols
G19.	Avoid visual distractions
D20.	Apply content to learners' daily lives
D21.	Promote the exchange of experiences and knowledge
D22.	Facilitate the inclusion of a tutor in the experience

In addition to restructuring, it was necessary to make the guidelines more practical and accessible to teachers. In the initial version, the guidelines presented more abstract orientations, with just the name of the guideline and the general description. To facilitate their understanding and application, each guideline now includes detailed information, such as goals, prerequisites, application examples, tips, expected results, and suggestions for computational resources (Figure 3). This aimed to offer a more direct entry point for instructors, promoting the adoption of the guidelines in specific activities, and not just in complete modules or entire courses.

Even after this detailing, the material's accessibility was still limited, as the revised version was only available in text document format (Apendice E). To broaden access and facilitate use by teachers, a website was developed based on Google Sites templates. Figure 4 presents the organization of the guidelines by LX elements, which serve as filters

Figure 3. Example of Detailed Guideline (Actual Version).


LEDG

Home

G17. Use appropriate fonts and colors, taking legibility into account.

General Description: This guideline helps create a clear visual design that highlights important information and facilitates the identification of key elements. Such identification can improve content comprehension, navigation, and visual comfort, making the presentation more pleasant and cohesive. This guideline can be applied both when selecting a digital resource and when designing new interactive material.

Goals

- Promote an effective reading experience that does not visually overwhelm students.
- Make content accessible for reading and understanding using readable fonts and high-contrast colors.

Prerequisite

- The teacher needs to choose fonts and colors that are easier to see and read, and adjust font and color settings to improve legibility.
- The teacher needs to observe students while they use digital resources. This can help identify areas where students are having difficulty seeing or using the materials.
- The teacher needs to adapt the digital resources as needed. This may include increasing font size, changing font and background colors, or providing other types of support.

How to apply the guideline:

1. Choose digital resources that allow customization, such as font and color adjustments.
2. Provide students with instructions on how to adjust font and color settings in the digital resources. This may include information on how to increase font size, change font and background colors, and adjust contrast.
3. Offer support to students who are having difficulty seeing or using the digital resources.

Example of Applying the Guideline:

- **Example 1:** The teacher can create slide presentations for their classes using large, readable fonts such as Arial or Verdana, and choose text and background colors with high contrast, such as black text on a white or yellow background. The teacher can avoid color combinations that may hinder readability, such as red text on a green background.
- **Example 2:** The teacher can distribute printed materials, such as exercises or readings, using a clear and legible font in an appropriate size (e.g., size 12 or 14), and choose a color palette that highlights titles and important sections without compromising readability. The teacher can avoid using colors that may be hard to distinguish on paper, such as very light shades of gray.
- **Example 3:** The teacher can configure the virtual learning environment by selecting themes or layouts that use legible fonts and color combinations that are easy to read, such as light backgrounds with dark text. They can also adjust the settings so that important links and buttons use colors that clearly stand out.

Tips

- Use sans-serif fonts such as Arial, Verdana, or Calibri, which are easier to read on digital screens. Avoid decorative or script fonts, as they can be difficult to understand.
- Use a consistent color palette across all your teaching materials. This helps students become familiar with the layout and the location of important information.
- Check how digital materials, such as presentations and documents, appear on different devices (computers, tablets, smartphones).
- Ask students if they have vision difficulties or reading preferences and adjust your font and color choices to meet their needs.
- Avoid excessive use of different colors and fonts on a single page or slide. A clean and simple design helps keep the focus on the content and improves readability.

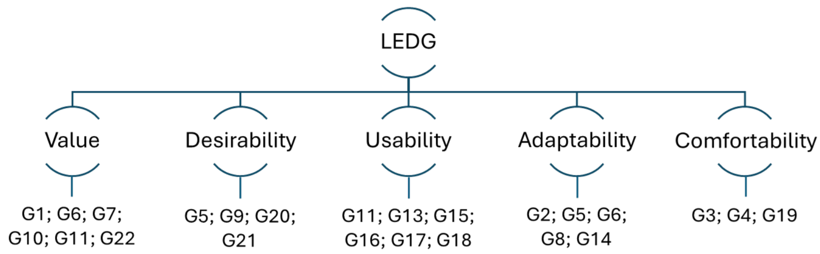
Ways of Evaluation:

- **Increased Effectiveness:** Are students able to use the digital resources independently? Can they complete tasks and projects effectively using the digital resource?
- **Increased Satisfaction:** Are students satisfied with the use of the digital resources? Do they find the resources easy to use?
- **Increased Acceptance of the Resource:** Do students think the resource is easy to use? Do they believe it is useful? Would they like to use it for other activities?

within the website itself to facilitate the identification and use of the guidelines by educators. By following the provided guidelines, educators are expected to create and/or redesign educational activities aligned with LX.

The process suggested on the website organizes the adoption of the guidelines into five steps: 1) Select: identify which LX elements are relevant to the learning objectives of the activity; 2) Include: choose guidelines that can be integrated into the activity, considering interaction, collaboration, and skill development; 3) Apply: consult examples and tips to employ the guidelines with computational resources; 4) Adjust: adapt the activ-

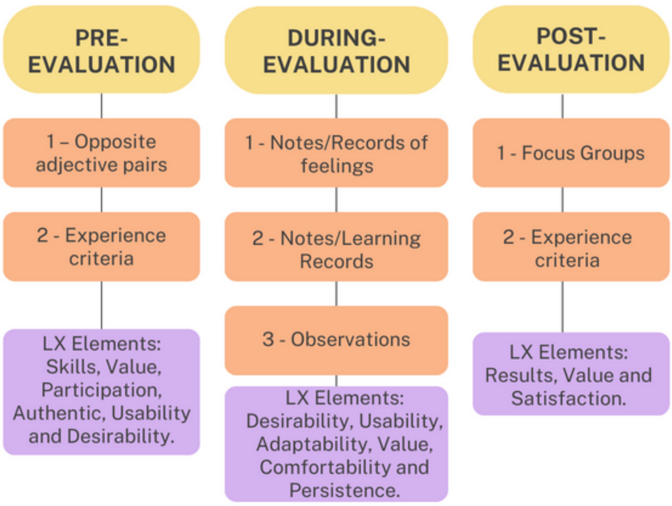
Figure 4. Organization of the Guidelines by LX Elements on the LEDG Website.



ity during its execution based on learners' reactions and engagement, promoting redesign when necessary; 5) Evaluate: reflect on the impact of the applied guidelines through collecting feedback and analyzing the obtained results. This workflow aims to support the instructor through all stages of the LX cycle, aligning with the LEDEF framework's proposal to foster an iterative process between design and evaluation.

Complementary to the LEDG, the LEEM contributes to the LEDEF by providing specific instruments for evaluating the LX at different stages of the educational process. LEEM encompasses three stages: pre-evaluation, during-evaluation, and post-evaluation [dos Santos et al. 2023b], as illustrated in Figure 5. In the pre-evaluation stage, pairs of opposite adjectives are used to identify the learners' initial profile, including their feelings and expectations regarding the use of computational resources. In the post-evaluation stage, the focus group technique is adopted to promote active listening to learners' perceptions of their experience. This allows not only the identification of learning outcomes but also encourages self-reflection and empowers students as protagonists.

Figure 5. LEEM Evaluation Model.



During the during-evaluation stage of LEEM, records and observations are carried out by both teachers and learners. Data is collected from multiple points of view, including students' self-reflections and teachers' feedback, enriching the understanding of LX by enabling comparisons across different perspectives. The integration of the LEEM with the LEDG strengthens LEDEF by establishing a systematic and learner-centered approach to evaluating educational experiences and interactions. This integration contributes to supporting the identification of strengths, and areas for improvement.

Approach to Evaluate the Solution. The feasibility study of the LEDG was conducted with 24 higher education instructors in Computer Science and Education, all experienced in using computational resources in their activities, leading to significant improvements in the guidelines, particularly regarding their interface, organization, and content. These enhancements facilitated their application by instructors and amplified their impact on the educational experience. The implemented changes, such as abbreviated titles, the use of IDs for quick navigation, and the adoption of dropdown menus, made the reading more objective and adaptable to selective viewing. Organizing the guidelines by elements, coupled with the indication of specific tools for each computational resource category, provided more targeted navigation and a selection better suited to instructors' needs. Based on these contributions, the LEDG evolved into its actual version.

The feasibility study of the LEEM was involved 19 teachers from different educational levels [dos Santos et al. 2023a]. The analysis identified areas for improvement, such as clarifying checklist items and better aligning them with each LX element's objectives. Although the instrument's length was identified as a negative point, it's understood that its use according to the guidelines, before, during, and after the activity, can minimize the fatigue associated with completion [dos Santos et al. 2025]. Generally, instructors found it practical, interesting, and suitable for evaluating the learning experience. However, its application in a real context was still necessary [dos Santos et al. 2024b].

For the LEEM, a case study was conducted with 23 learners and one instructor from a Software Engineering course [dos Santos et al. 2024a]. The application of the LEEM allowed for evaluating LX before, during, and after the educational activity. The data revealed that integrating computational resources contributed to a more comfortable and engaging. Variations in interest were also observed throughout the activity, as well as distinct preferences between individual and collaborative work. Applying the checklist at different times favored the collection of multiple perspectives, pointing out both positive aspects and areas for improvement, such as greater clarity in instructions and scale appropriateness. The feedback and suggestions helped make the LEEM more objective and accessible, highlighting its effectiveness in supporting teachers.

The LEDEF case study was conducted with 19 students and one instructor from an Algorithms and Programming Techniques course [Silva et al. 2025]. The guidelines were implemented focusing on the Desirability element (G3, G5, G9, G20, and G21), but the redesign revealed other elements, such as Value, particularly through the importance of guidance and feedback for more timid learners. Learners' perceptions of group work also shifted: initially preferring individual tasks, many later reported positive experiences with collaboration. This process underscored the instructor's role in mediating activities, fostering social skills and self-confidence. The checklist review further supported the instructor in adapting practices and enhancing the overall learning experience.

The iterative nature of LEDEF, with cycles of design and evaluation, made these adaptations possible. The use of tools like Notion and Prezi supported organization and collaboration among learners, in addition to introducing them to new study methods. Many showed interest in using these tools in future contexts. The possibility of choosing the study environment and time also strengthened autonomy and responsibility. However, the study pointed out adaptation difficulties for some learners less familiar with technology, which caused discomfort, especially in public exposure situations.

6. Conclusion and Future Work

This research presents a framework for the design and evaluation of LX to support educational instructors and LX designers. This thesis addressed the research question: "How to design and evaluate LX, considering the appropriate elements and technologies to support educational experiences?". To achieve this purpose, a LEDEF was developed within the context of this doctorate. The LEDEF focuses on these two stages of the LX lifecycle, linking them to other stages such as planning, application, and redesign, to facilitate the gradual inclusion of elements and technologies. These choices are the instructor's responsibility, who can be guided by a pre-evaluation or by previous experiences with learners. LEDEF offers a structure, but its process is flexible, granting to the instructor the autonomy and adaptability needed to meet the specificities of the activity and class.

The novelty of this research lies in presenting a framework guided by LX elements that favor the adaptation of educational activities, considering constant changes in learner profiles and the educational landscape. LEDEF's ability to incorporate new guidelines and technologies as experiences unfold provides a dynamic approach that enriches the framework, keeping it updated and relevant throughout the educational process. Although LEDEF's guidelines are geared towards the use of computational resources, those that do not involve usability aspects can be applied without these resources, leaving it to the instructor's discretion to adapt them to the target audience's needs. This work extends an invitation to higher education instructors to reflect on their practices. While there is a more evident effort and deeper discussions about the use of computational resources in basic education, higher education has a lack of investment and debate around these issues.

Despite the contributions, some limitations should be considered. The systematic review included studies only up to mid-2021. Identifying LX elements in publications with unclear descriptions required author inferences, which are subject to bias, even when reviewed by experts. Understanding students' perceptions based solely on self-reports may compromise data reliability; LEDEF recommends triangulation with direct observations to mitigate this. Moreover, the feasibility and evaluation studies involved relatively small samples of instructors and students, whose profiles (e.g., experience with computational resources, educational context, and prior exposure to LX design) may not fully represent the broader population. Therefore, the results cannot be generalized. Additionally, LEDEF's scalability may be constrained in large or highly heterogeneous classes, and the framework's adoption could require investment in instructor training and preparation, particularly in diverse or resource-limited educational settings.

Future work may focus on adapting the LEDEF to better support inclusive education by considering diverse learner profiles, such as neurodivergent students or those with disabilities. Investigating the automation of LEDEF through AI tools could reduce instructors' workload, offering real-time feedback and optimizing the planning and evaluation process. Expanding training initiatives for educators, especially through hybrid or online formats, can broaden adoption and foster practical engagement with the framework. Additionally, new experimental studies are needed to validate LEDEF in larger and more heterogeneous classes, helping assess its scalability.

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Availability of Artifacts

- Appendix A (LEDG):
  `https://sites.google.com/view/lexdg/home`
- Appendix B: (LEEM):
  `https://figshare.com/s/c413a259aa038535edcd`
- Appendix C: (Technical Report of SMS 1)
  `https://figshare.com/s/3eb8195b1715f596c883`
- Appendix D: (Technical Report of SMS 2)
  `https://figshare.com/s/57a28e783af82620ce13`
- Appendix E: (Versioning of the LEDG)
  `https://dx.doi.org/10.6084/m9.figshare.23699250`

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