A step by step methodology for software design of a Learning Analytics tool in Latin America: A Case Study in Ecuador

Margarita Ortiz-Rojas, Ricardo Maya, Alberto Jimenez*, Isabel Hilliger†, Katherine Chiluiza‡
*Information Technology Center
Escuela Superior Politécnica del Litoral, ESPOL, Guayaquil, Ecuador
{maelorti,albjimen,rmaya}@espol.edu.ec
†Department of Computer Science
Pontificia Universidad Catolica de Chile, Santiago de Chile, Chile
ihillige@ing.puc.cl
‡Faculty of Electricty and Computer Science
Escuela Superior Politécnica del Litoral, ESPOL, Guayaquil, Ecuador
kchilui@espol.edu.ec

***Abstract*—One main objective for software developers is to find the right approach to design and develop a tool faster and effectively. In the context of Learning Analytics (LA) in Latin America, this becomes more complicated due to a lack of clear guidelines that could guide Higher Education institutions (HEI) to the design of LA tools. Thus, this study describes a step by step methodology for software design of a LA tool. The methodology combines the phases of Design Thinking and the testing components of Human-Computer Interaction theory. It starts from the LALA framework, a set of methodologies that guides HEI to create a baseline of LA needs in the context of a project named LALA (Learning Analytics in Latin America). The needs are then materialized into a tool after a user-centered iterative process takes place. The methodology is not only adaptable for HEI that have never implemented LA tool, but also for HEI that have implemented an LA tool and need to make some upgrades. For validation purposes, this article presents a case study of adopting this methodology in the design of visualizations of an academic counseling tool, and discusses the results to illustrate its use for other HEI.**

***Keywords*-Learning Analytics, software design, Design Thinking, Human-Computer Interaction, Latin America**

I. Introduction

One key challenge for software developers is to find the right approach that helps them design software faster, efficiently, and cost-effectively [1]. This evolution has passed from a more linear process to a more iterative one. For instance, in the traditional waterfall model, each step must be completed before moving to the next phase [2], not allowing changes in the initial requirements [3]. In contrast, in agile methodologies, such as scrum or extreme programming, the development process is improved due to the partial deliverables that can be tested with the clients throughout the process, allowing the designers to adapt to different changes in requirements. [4], [5].

Since one model does not fit all, designers are now creating hybrid models that suit their needs. For instance, in [1], [6], the authors propose a combination of design thinking and agile practices, while in [7], the combination also includes user experience design.

In the specific case of software design of Learning Analytic (LA) tools, one issue arises. Most studies mention how the authors designed the tool but without a step by step process. For instance, in [8] a user-centered design is declared by the authors as the method to design the tool, but without much information about the specific steps followed to obtain a testable dashboard, while in [9] just the purpose of the tool and how it works are mentioned, leaving apart the design process. Not mentioning the specific methodology is acceptable in Anglo Saxon countries where there are already some initiatives and even policies for the adoption of LA [10]. However, the information is insufficient for Latin America institutions since there is a lack of local capacity to adopt LA due to clear guidelines [11].

In order to build capacity for the design of LA tools in Latin America, this study describes an iterative methodology to develop an LA tool for meeting needs of higher education stakeholders. This methodology was elaborated in the context of the LALA project - Learning Analytics in Latin America. One deliverable of this project is the LALA framework, which is structured in 4 dimensions that are addressed in 4 manuals, which could be used jointly or separately: 1) institutional, 2) technological, 3) ethical, and 4) communal [12]. For the design of a LA tool, the technological manual provides technical considerations for the design, implementation and evaluation of a tool from a broad perspective. To complement this perspective with further detail, this paper provides a step by step methodology to develop a LA tool based on two design approaches: desing thinking and human-computer interaction. Besides, a case study of the use of the methodology in one HEI is presented to illustrate how it could be adopted in any institution in the region.

The paper is organized as follows: Section 2 presents

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the conceptual framework involving Design Thinking and Human-Computer Interaction. Next, section 3 details our proposed methodology. Section 4 presents a case study that validates the methodology. Finally, Section 5 presents the conclusions and further recommendations.

II. Conceptual Framework

A. Design Thinking

Design Thinking (DT) has become one of the paradigms used to deal with obstacles in many fields [13], as the design concept is not limited to specific disciplines but is related to all those that require a design process. Therefore, there are many concepts and definitions about it, each linked to a particular field [14] which has led to defining it in different ways such as [15] [16], concluding that there is no general definition. [17]. Starting from this point, different concepts and definitions about what design thinking is can be found [18] [19], but the highly used definition defines it as a discipline that uses methods of designers to meet people's needs with what is technologically feasible [20].

The DT process is integrated into the group of iterative processes, such as agile methodologies, to determine the needs of the users and redefine the process using new innovative strategies. These needs can only be discovered after an iteration process with the stakeholders, taking into account how the product designers work, using their process to help methodically apply human-centered techniques to solving problems. As this technique allows the generation of new innovative ideas, it can be implemented in any field which has caused the popularity increase over the years.

DT is a process which involves a series of phases to be followed and not necessarily in a sequential mode or step by step, and for such reason, some variants can be found in practice. Nevertheless, all of them keep the same principles described first by Nobel Prize laureate Herbert Simon [21]. The phases presented below were proposed by the Hasso-Plattner Institute of Design at Stanford [22] since they are well known in applying and teaching DT.

1) Empathize: In this starting phase is necessary to establish a connection with users, trying to obtain a solid knowledge and comprehension about their needs and the field in which they are involved, being this way even the immersion in their physical environment.

2) Define: With the information gathered from the empathize stage, in this phase all that information is put together, and an analysis process is followed in order to seek what is meaningful and what brings new perspectives and innovative ideas. Furthermore, the problem definition is presented at this stage, and the way how it is elaborated will help designers to choose the right approach to solve the problem and provide great ideas.

3) Ideate: In the ideate phase, designers generate ideas with the primary objective of doing so as much as they can "thinking outside of the box" in order to identify new solutions to the proposed problem.

4) Prototype: Here the ideas become real, building prototypes to turn ideas into tangible inexpensive things, but functional enough to test them with the team or with another group of people, but with the central intention of finding the best solution for the defined problems.

5) Test: During the testing phase, all built prototypes are tested with real users, and this will help to identify improvements or failures to be solved, which would make designers return to previous phases in an iterative process.

B. Human Computer Interaction

The human-computer interaction (HCI) is a multidisciplinary field of study that focuses on the design of technology, especially in the interaction between humans and computers [23]. It also overlaps with areas such as user-centered design, user interface design, and user experience [24]. HCI has expanded to incorporate multiple disciplines, such as computing, cognitive science, and human factor [25].

1) Cognitive Model: Human Interaction has adopted models of psychology, sociology, and anthropology to understand human behavior. Among them is the cognitive model, which studies how human beings know, think, and remember, focusing the attention on how they elaborate, create, and interpret information as thinking subjects. Goals, operators, methods, and selection rules (GOMS), is a cognitive model that uses an analysis strategy based on separating a goal that the user can make directly into smaller goals. The GOMS method has been used as a method to perform task analysis by users [26].

- Goals: What the user intends to accomplish
- Operators: Actions that are performed to reach to the goal
- Methods: Sequences of operators that accomplish a goal
- Selection rules: Selection of certain methods to accomplish a single goal

2) Usability: It measures the quality of the experience a user has when interacting with a system [27]. It also involves reviewing a series of aspects related to the use of the system. Usability has a set of attributes and underlying questions, such as:

- Ease of learning: how easy is it for users to perform basic tasks the first time they use the system?
- Efficacy: Once the user has learned to use the system, how long does it take to complete the basic tasks?
- Ease of memory: When users return to the system after a period of not using it, how complicated is it to reconnect with the system?
- Errors: How many mistakes does the user make, how serious are they, and how do they recover from them?
- Satisfaction: How comfortable are the users using the system?

- Utility: Refers to the functionality of the system. Does the user achieve his/her objectives within the interface?

III. Proposed Methodology

The proposed methodology combines elements from the theories above, adapted to the context of a LA design tool. Figure 1 depicts the methodology. From the DT elements previously described, we adopted the stages with two main differences: First, the ideation stage occurs before and during prototyping and testing, and not only before. Second, the prototyping and testing stage are divided in two phases: one focused on low or mid fidelity prototypes testing only layout, and the other designing a high fidelity prototype, testing usability. The latter, a concept related to Human Computer Interaction.This iterative approach involves stakeholders from beginning to end. In the case of LA adoption, these stakeholders are mainly students, teaching staff and institutional managers, who have to be involved in different ways throughout the five DT phases. A detailed explanation of each stage is presented next:

A. Empathize

In this stage, the institution's needs and problems to use LA are found. To achieve this goal, the institutional dimension of the LALA Framework is used as a guideline to assess the needs of higher education stakeholders [12].Out of the four dimensions that are explained: First, a diagnosis is performed using the LALA Canvas, an instrument that helps to identify the current institutions' political context, desired behavior, change strategy, internal abilities, influential actors, measurement, and evaluation plan. Next, interviews are carried out with institutional leaders, professors, and students to understand the political context and the institutional needs, as well as the ethical and privacy considerations that the institution should take into account. Finally, surveys are filled out by teaching staff and students to identify what is expected from the use of educational data, so needs could be identified by contrasting the current institutional context with stakeholder expectations.

B. Define

The triangulation of the different sources of information from the previous step provides a clear idea of what the institution needs (e.g., provide feedback to teachers about their performance). This analysis might lead to the development of a tool that can satisfy that need or just the elaboration of institutional policies. If a tool is needed, the path continues. Requirements are obtained for the design of the tool. If it is already developed, and only a newer version needed, questions through interviews or questionnaires such as: "How can we improve the tool?" or "what don't you like about the tool?" could give sufficient feedback. Observations on how users use the tools can also provide information on system requirements. On the other hand, if the LA tool has never been implemented in the institution, it is better to present demo versions, mock-ups or prototypes through focus groups or interviews of tools already created (previous research), so that potential users can have a baseline to brainstorm.

C. Ideate

Once all requirements are gathered, they are analyzed. As in design thinking, designers come up with different ways to visualize the general layout of the tool. This stage not only happens before the next one, but also during based on changes that the user might suggest.

D. Prototype and testing (layout)

In this stage, end-users will be asked their opinions about layout, color, and visualizations. To achieve this, there are different ways to test the design concepts: Low fidelity and medium fidelity. For instance, in low fidelity, one can use sketching, storyboarding, wireframe, while in medium fidelity, mockups are used. To start with one or another depends on the LA tool to be designed. If there are already previous tools developed, it is better to skip low fidelity prototyping because visualization is a crucial aspect to take into consideration [28]. Hence, they help users have a clearer idea of what the tool would look like. On the other hand, if it is a brand new tool, low fidelity prototyping should be used first because it gives the best scenario for brainstorming of different design ideas [29]. Once the prototype is designed, it will be part of an iterative process. This will elicit more requirements that were not planned in the earlier stage and will force designers to create new versions of the prototype. It is up to the design team to continue this iterative process until the target audience agrees on the general layout, color, and visualizations of the tool. It is also possible that the original prototype designed in the previous stage would not be accepted by the audience. Hence, a new one is tested.

E. Prototype and testing(HCI)

Unlike the previous stage where the focus was on layout and colors, this one emphasizes testing in a real context, with a high fidelity prototype that shows real data and interacts with the user. Here HCI concepts are implemented. Before the testing, usability goal, tasks, and thresholds are set. To measure the usability of the system in the testing phase, the following steps are followed:

1) Identify a task to be performed within the system
2) Indicate the steps that the user must perform to perform the task within the system
3) Set a limited time that the user must take to complete the task
4) Indicate the threshold to accept the task as approved
5) Associate the task with more usability components.

The iteration will stop until the threshold is reached, having the final version of the tool ready.

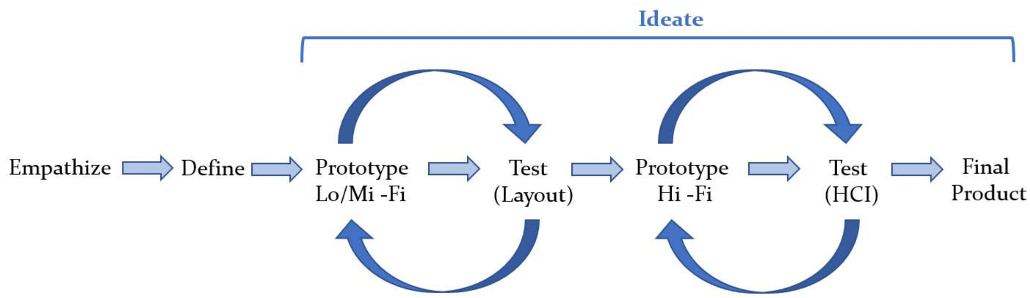


Figure 1: Proposed methodology

F. Final product

It refers to the beta version of the tool.

IV. Case Study

The proposed methodology was applied for the improvement of an already designed learning analytic tool (a counseling system), in an engineering-oriented university in Ecuador. The entire process took nine months and ended up with a beta version of the tool. Each step is described as follows:

A. Empathize

Following the LALA Framework, the LALA Canvas was applied followed by interviews that were conducted with eight institutional leaders and surveys that were applied to 204 students and 24 teachers. Furthermore, focus groups were also conducted with seven teachers and four students separately. The guiding questions for interviews and focus groups were obtained from the institutional manual of the LALA framework, as well as the surveys formats. Since the term Learning Analytics is not well known in the institution, the term " academic data" or "data" was used. One sample question was: "How else could student and teacher data be used to improve understanding of their academic and teaching performance at the university?"

B. Define

Findings from the triangulation of the data collected from the different focus groups, interviews and surveys showed that the current LA used for the academic counseling process needed improvement. Since teachers already knew what a counseling system was, requirements were gathered by asking 23 teachers what additional information they would like to see in the tool and how they would like to visualize it.

C. Ideate

The teachers' feedback helped us brainstorm the possible sections that the system would have (Figure 2).

D. Prototype Lo-fidelity/mid-fidelity and testing layout

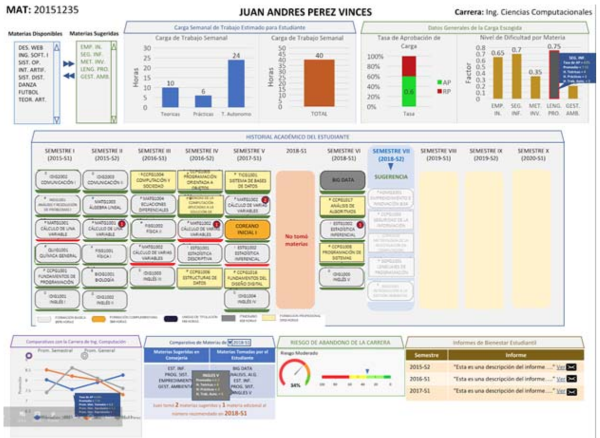
An already designed counseling dashboard was adapted from one of the LALA project's partner universities, using Microsoft PowerPoint (Figure 2a). Then, teachers were asked from different faculties whether they agreed with the location of the different sections of the dashboard and asked them to choose from different options, which visualization could help them understand the data in a better way (Figure 3). The feedback received during these sessions made the designers realize that the dashboard looked too crowded. Thus, a second version of the counseling system was ideated with cards (Figure 2b) and iterated. In total, ten teachers participated.

E. Prototype hi-fidelity and testing HCI

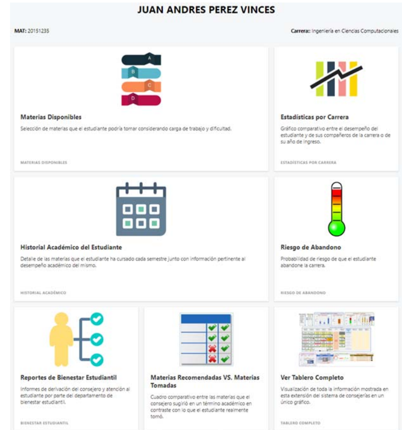
Before creating a high fidelity prototype, the usability goals were set. It consist of a task, process, time, usability goal and usability component. Table 1 shows an example of one of them. When role-playing how the teachers would interact with the system, the designers realized the system was being treated as something isolated from the current counseling system already implemented in the university. Thus, it was decided to change the layout again, this time, grouping the cards in three sections with different subsections (Figure 4). The third ideation consists of three pop-up windows that are described below:

1) Academic History: It shows all the subjects taken by the students in the different academic periods. The counselor can review the statistics of the course in which the student is registered as well as all the courses taught during the academic period (Figure 4a).

2) Additional Statistics: It shows: a) graphs where the counselor can observe the academic average of the student per semester and compare it with all the students of the same program; b) a comparison between the registered subjects and the suggested subjects for previous semesters; c) the risk of abandonment of the student based on a predictive model, and d) the history of the student getting psychological, medical or financial help from the Student Welfare Department (Figure 4b).

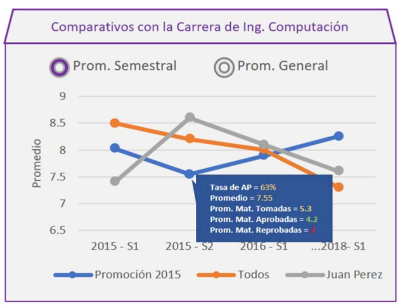


(a) First Ideation: Counseling system Mockup

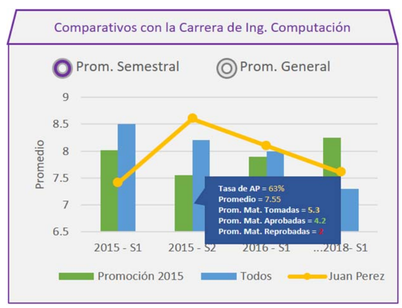


(b) Second Ideation: Counseling system in cards version

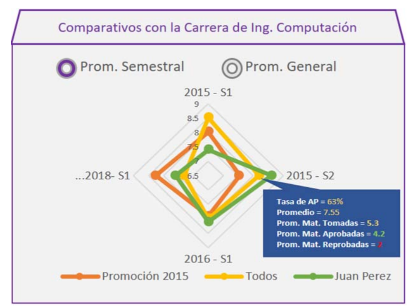
Figure 2: Visualization options



(a) First option



(b) Second option



(c) Third option

Figure 3: Testing visualization options

3) Available Subjects: List the subjects that the counselor can suggest to the student for the next academic record. When selecting the subject, historical data is loaded, such as: hourly load, level of difficulty of the same. With this information, the counselor can add and remove subjects to find the appropriate academic load for the student (Figure 4c). The prototype was then programmed and tested with 11 teachers. Their feedback was focused on minor changes in titles and colors.

F. Final product

A beta version of the counseling system was developed and incorporated in the current university system. A demo version is available at https://200.10.150.55/

V. Conclusions

This study presented a proposal for a step by step methodology to develop a LA tool in Latin America. Furthermore, a case study is presented applying the aforementioned methodology. It is expected that this methodology creates a link that complements the LALA framework to the design of a LA tool. The authors are also aware that there could be alternative methodologies to the design of LA tools. Nevertheless, taking into consideration the Latin America context, it is considered that this step by step procedure could give clearer guidelines for software designers and researchers in Higher education institutions. As further research suggestions, it is expected to see other case studies where the proposed methodology has been applied to keep its validation process. Especially in the particular case of a Higher Education Institution that has never implemented a LA tool.

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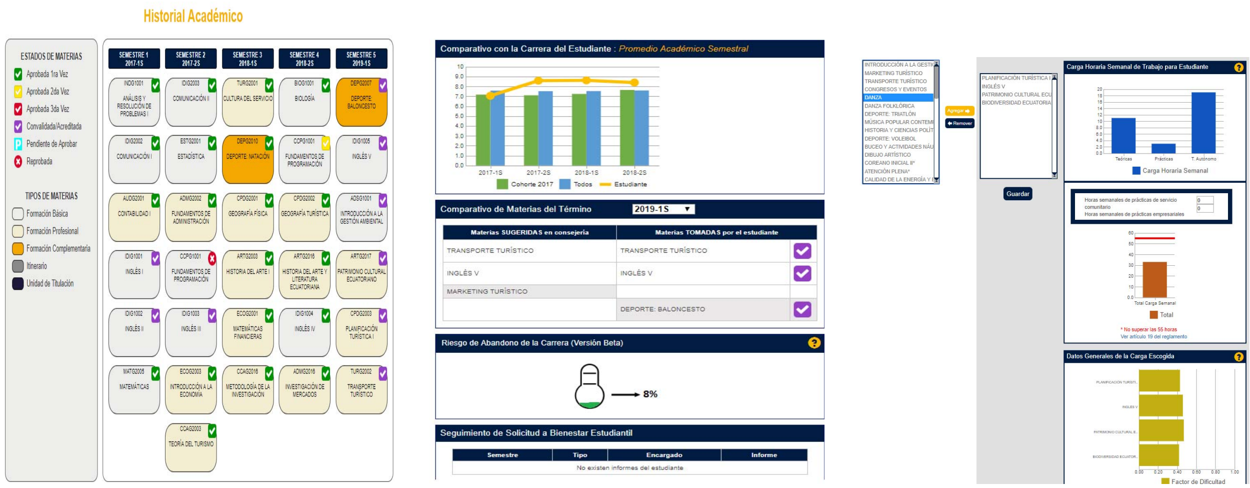

(a) Academic History (b) Additional Statistics (c) Available Subjects

Figure 4: Third Ideation: High fidelity prototype in pop-up windows

Table I: Example of a task in a module

Task Module: Academic History
Process - The user will be asked to go to the window academic history - The user will be asked: How many students obtained the same average in the subject Industrial Processes? - The userś response will be recorded in the form
Time 1 min
Usability goals The user can identify how many students obtained the same average without major effort: - 90 of users can identify the amount of students
Usability component Efficiency

References

[1] K. Gurusamy, N. Srinivasaraghavan, and S. Adikari, "An integrated framework for design thinking and agile methods for digital transformation," in *International Conference of Design, User Experience, and Usability*. Springer, 2016, pp. 34–42.

[2] R. Turner, *Software System Methodology*. Berlin, Heidelberg: Springer Berlin Heidelberg, 2018, pp. 117–120. [Online]. Available: https://doi.org/10.1007/978-3-662-55565-1_13

[3] K. Ali, "A study of software development life cycle process models." *International Journal of Advanced Research in Computer Science*, vol. 8, no. 1, 2017.

[4] B. Henderson-Sellers and M. Serour, "Creating a dual-agility method: The value of method engineering," *Journal of Database Management (JDM)*, vol. 16, no. 4, pp. 1–24, 2005.

[5] G. Lee and W. Xia, "Toward agile: An integrated analysis of quantitative and qualitative field data on software development agility." *Mis Quarterly*, vol. 34, no. 1, 2010.

[6] O. Sohaib, H. Solanki, N. Dhaliwa, W. Hussain, and M. Asif, "Integrating design thinking into extreme programming," *Journal of Ambient Intelligence and Humanized Computing*, pp. 1–8, 2018.

[7] S. Adikari, C. McDonald, and J. Campbell, "Reframed contexts: design thinking for agile user experience design," in *International Conference of Design, User Experience, and Usability*. Springer, 2013, pp. 3–12.

[8] M. Millecamp, F. Gutiérrez, S. Charleer, K. Verbert, and T. De Laet, "A qualitative evaluation of a learning dashboard to support advisor-student dialogues," in *Proceedings of the 8th international conference on learning analytics and knowledge*. ACM, 2018, pp. 56–60.

[9] I.-H. Hsiao, S. K. Pandhalkudi Govindarajan, and Y.-L. Lin, "Semantic visual analytics for today's programming courses," in *Proceedings of the Sixth International Conference on Learning Analytics & Knowledge*, ser. LAK '16. New York, NY, USA: ACM, 2016, pp. 48–53. [Online]. Available: http://doi.acm.org/10.1145/2883851.2883915

[10] Y.-S. Tsai and D. Gasevic, "Learning analytics in higher education—challenges and policies: a review of eight learning analytics policies," in *Proceedings of the seventh international learning analytics & knowledge conference*. ACM, 2017, pp. 233–242.

[11] J. Maldonado-Mahauad, I. Hilliger, T. De Laet, M. Millecamp, K. Verbert, X. Ochoa, and M. Pérez-Sanagustín, "The lala project: Building capacity to use learning analytics to improve higher education in latin america," 2018.

[12] M. Sanagustín, I. Hilliger, J. Maldonado, R. Pérez, L. Ramírez, P. Muñoz-Merino, Y.-S. Tsai, M. Ortiz-Rojas, T. Broos, M. Zuñiga-Prieto, E. Sheihing, and W.-W. Alexander, "Lala framework," LALA Project, Tech. Rep., 2019. [Online]. Available: https://www.lalaproject.org/wp-content/uploads/2019/04/LALA_framework_Spanish.pdf

[13] K. Dorst, "The nature of design thinking," in *Design thinking research symposium*. DAB Documents, 2010.

[14] A. Hevner and S. Chatterjee, *Design research in information systems: theory and practice*. Springer Science & Business Media, 2010, vol. 22.

[15] E. Iee, "Ieee standard glossary of software engineering terminology," 1990.

[16] D. Benyon, "Designing interactive systems (2: a uppl.)," *Harlow: Pearson Education Limited*, 2010.

[17] P. Ralph and Y. Wand, "A proposal for a formal definition of the design concept," in *Design requirements engineering: A ten-year perspective*. Springer, 2009, pp. 103–136.

[18] T. Lindberg, R. Gumienny, B. Jobst, and C. Meinel, "Is there a need for a design thinking process," in *Design thinking research symposium*, vol. 8, 2010, pp. 243–254.

[19] N. Cross, K. Dorst, and N. Roozenburg, *Research in design thinking*. Delft University Press, 1992.

[20] T. Brown *et al.*, "Design thinking," *Harvard business review*, vol. 86, no. 6, p. 84, 2008.

[21] H. A. Simon, "The sciences of the artificial," *Cambridge, MA*, 1969.

[22] H. Plattner, "An introduction to design thinking process guide," *The Institute of Design at Stanford: Stanford*, 2010.

[23] A. Poole and L. J. Ball, "Eye tracking in hci and usability research," in *Encyclopedia of human computer interaction*. IGI Global, 2006, pp. 211–219.

[24] J. Karat and C.-M. Karat, "The evolution of user-centered focus in the human-computer interaction field," *IBM Systems Journal*, vol. 42, no. 4, pp. 532–541, 2003.

[25] C. Ghaoui, *Encyclopedia of human computer interaction*. IGI Global, 2005.

[26] J. M. Carroll, *HCI models, theories, and frameworks: Toward a multidisciplinary science*. Elsevier, 2003.

[27] J. Nielsen, "Usability inspection methods," in *Conference companion on Human factors in computing systems*. ACM, 1994, pp. 413–414.

[28] B. Saket, D. Moritz, H. Lin, V. Dibia, C. Demiralp, and J. Heer, "Beyond heuristics: Learning visualization design," *arXiv preprint arXiv:1807.06641*, 2018.

[29] K. Moffatt, J. McGrenere, B. Purves, and M. Klawe, "The participatory design of a sound and image enhanced daily planner for people with aphasia," in *Proceedings of the SIGCHI conference on Human factors in computing systems*. ACM, 2004, pp. 407–414.