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User-Discovery Research as the Foundation for Designing and Measuring Usability of Interactive Systems.

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Abstract

This working paper examines how the usability of interactive systems can be systematically measured and demonstrated, with particular attention to the implementation of user-discovery research in the design of user interfaces (UIs) within learning design and interactive systems for educational technology (EdTech) projects that support formal learning and enhance engagement. Usability has been defined in terms of effectiveness and efficiency, but its operationalisation through user satisfaction still receives less attention in EdTech contexts. This limitation is especially critical, as the assessment of usability must also address the optimisation of the user experience, which, in turn, can ensure meaningful learning outcomes. The paper reviews existing frameworks for measuring the usability of interactive systems and identifies key dimensions, including effectiveness, efficiency, satisfaction, and learnability, as metrics. It then discusses the importance of a user-discovery approach combined with the Iterative Design cycle as qualitative metrics, which are fundamental to meaningful assessment of quantitative performance metrics, that usually focus on how well the system/solution actually works. Based on the findings from the empirical study conducted on user-discovery, the paper proposes an integrated evaluation perspective that includes an iterative loop and insight into metrics, extending traditional usability assessment to incorporate user-discovery research. This approach positions the usability measurement of an interactive system as a multi-layered construct encompassing user experience, interaction quality and educational impact. Hence, it contributes to the mainstream body of research by offering a structured foundation for a mixed-methods approach to evaluating interactive systems in learning design and human-computer interaction in education, and by highlighting the need for orderliness in usability metrics for efficient trade-off decisions.

Keywords: Iterative Design; User-Discovery Research, Interactive Systems; Learner Experience; Human-Computer Interaction.

This working paper stems from the ongoing research into the design and evaluation of the Adaptive Language Mediation System project's user interface (UI).

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1. Introduction

Interactive systems are designed purposely as means to an end, and this end is usually something deeper and more valuable than just using the system: that is, interactive systems are designed to enable users to accomplish specific goals within a given application domain (Alan Dix et al., 2004; Sommerville, 2016). For instance, a simulated learning environment enables a learner to experiment, fail, and retry a specific task in a safe environment, leading to gaining an understanding that passive reading alone would not achieve. In this instance, the interactive system that enabled the simulation is not the destination nor the purpose, but a carefully designed pathway toward understanding, behavioural change, and acquisition of a near-real-world experience.

Given this fact, assessment of usability becomes a critical quality attribute, determining whether users can effectively, efficiently, and satisfactorily achieve their defined goals (their ends) through the system. Despite its importance, usability is often treated as a loosely defined concept, lacking consistent operationalisation with more emphasis on the quantitative metrics at the expense of optimising user experience and satisfaction, particularly in EdTech, where system success must also account for the ability to greatly optimise learner experience and maximise learning outcomes (Schnepf & Rogers, 2022). This concern led to the central question of this working paper:

How can the usability of an interactive system be demonstrated and measured in a systematic and meaningful way?

2. Conceptualising Usability

The most authoritative definition of Usability is linked with the framework of the International Organisation for Standardisation (ISO 9241-11), which defines “usability as the extent to which a system, product, or service can be used by specified users to achieve specified goals with effectiveness, efficiency, and satisfaction in a specified context of use” (ISO 9241-11:2018, 2018). This definition characterises usability in measurable terms and breaks usability into three core dimensions: effectiveness, efficiency, and satisfaction. Also, in an extension, Jakob Nielsen added complementary perspectives, which apply to practical design, to include learnability, memorability, and error tolerance (Izzah Isharah, 2024). Together, these perspectives suggest that usability is a multi-dimensional construct that integrates both objective performance measures and subjective user perceptions.

There is so much to address in the two definitions; the ISO definition emphasises “specified users”, “specified goals”, and “specified context”. This underlines the importance of identifying potential users and their expectations, the use cases, and contexts (ISO 9241-210: 2019, 2019). Ideally, in a well-scoped project, designers usually aim to identify the target user group, main tasks, and context of use. But in reality, these are often partially known because, in some situations, users may be broad or evolving, and even the context may change or expand - this uncertainty underscores the importance of understanding trade-off decisions. These facts make the user discovery research proposed in this working paper more meaningful and needful so that the design process of UIs and interactive systems becomes an iterative process of discovering and refining.

Conceptualising usability of interactive systems should not be understood solely as an interface property, but rather as an emergent quality arising from the interaction between users, tasks, and technological artefacts within a specific context of use.

3. Dimensions and Metrics of Usability

The ISO's definition and Jakob Nielsen's definition of usability collectively highlight some components (also known as dimensions) as metrics of usability in interactive systems design, including effectiveness, efficiency, satisfaction, learnability, and memorability, to demonstrate usability empirically. It is therefore necessary to elaborate on the listed components, moving away from their abstract perspectives and into their description as measurable indicators. Table 1.1 depicts the descriptions of the core components that are listed in their definitions.

Table 1.1: Descriptions of Key Usability Components

Components	Descriptions	Metric Examples
Effectiveness	Measures the accuracy and completeness with which users achieve specified goals.	Task success rate, error rate, and task completion quality.
Efficiency	Measure how quickly (speed) and the rate of resources expended in relation to task achievement.	Time on task, number of interactions (clicks, steps), and cognitive load.
Satisfaction	This metric measure how users feel about using the system. That is, users' subjective perceptions and attitudes toward the system.	Standardised questionnaires, survey (e.g., System Usability Scale (SUS)), and user feedback.
Learnability	Measures the ease with which new users can begin effective interaction. That is, how easy it is for new users to learn and interact with the system.	Time to first successful task, learning curve, reliance on help features.
Memorability	Measures how easily users can remember how to use the system after a long period of not using it.	Time to relearn after a break, the number of errors after returning, and the need for help.

4. Empirical study: User-Discovery Research

The findings from implementing a user-discovery research approach in the design process of the UI for the Adaptive Language Mediation System project, whose goal is to support the learning process for a multilingual student population, are explained as follows:

We need to build a web-based user interface (UI) to enable students to connect and interact with the Adaptive Language Mediation System (the system) while in the classroom and receive their teacher's speech in translated texts in their selected languages – the main goal of the project.

Being a well-planned project, we decided to build a simple UI with the basic features embedded as outlined below:

- i. Text window: The pane that displays the transcribed speech of the teacher in text format.

- ii. Connect and Disconnect buttons: Visual, clickable buttons to enable the users to connect with the system and disengage from the system at their own will.
- iii. Language drop-down menu: A hidden pane that contains a list of languages to allow users to select their preferred language for the text to be displayed.
- iv. Download Transcript button: To allow students to save their teacher's speech in text format so they can revisit, enhancing learning retention.

Instead of building the UI based on assumptions or intuition, we decided to conduct basic, but meaningful user discovery research with six (6) real users: international students whose first languages differ from each other, and none of whom is English.

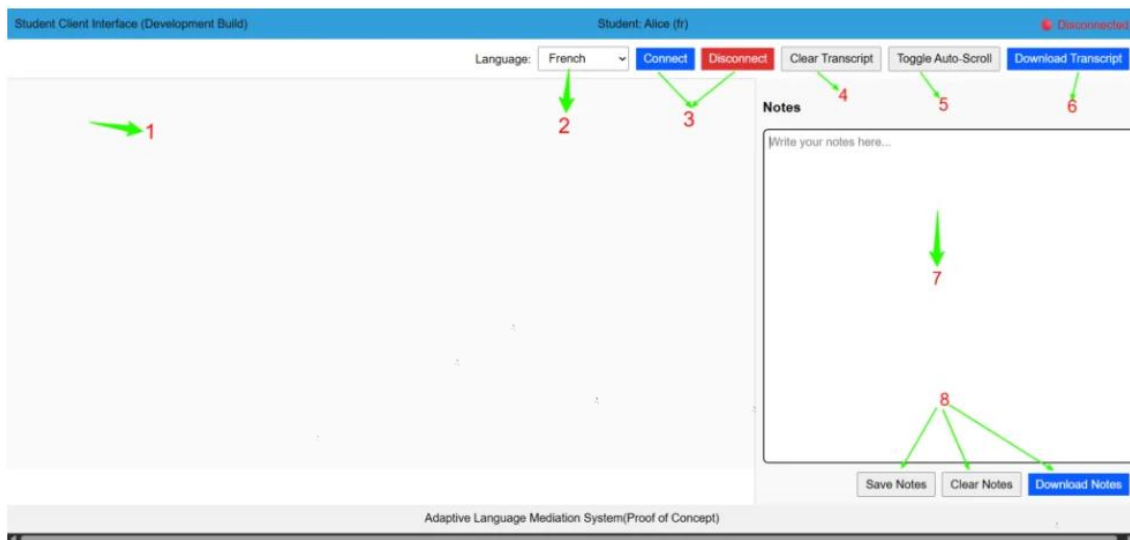
The interview method was used, and during this session, the students were asked to list two (2) features with reasons each they would love to see if they found a system (platform) that could enhance and support their classroom learning experience at their universities, since the language of instruction at their universities is not the first language of any of them. In addition to the features we already anticipated to embed in the UI, the students listed some thoughtful, sensible, and very useful features outlined below:

- i. Auto scrolling: this feature will enable the translation window to scroll up automatically when text fills the display area. This feature, as trivial as it seems, can definitely support attention and enhance learner engagement during the learning process.
- ii. Note-taking: - The feature will enable students to jot down notes during lecture periods using their device's keyboard.
- iii. Save notes: This feature allows user to save their own notes in a preferred format; PDF, Word, etc.
- iv. Clear transcription button: To clear or reset the display pane. It facilitates a segmented learning cycle and focused discourse analysis.

Given these contributions, we were able to design a simplified UI prototype with a clean layout and consistent navigation patterns for effectiveness and learnability. Early testing of the prototype indicated that users could achieve their goal successfully (effectively), and faster (efficiency), with little or no guidance at all (learnability), and could return to use it after a long break without any confusion (memorability). A feedback session was conducted, and it indicates an overall positive experience (satisfaction).

Figure 1.1 shows the UI of the Adaptive Language Mediation System project. The design is aided by the implementation of a user-discovery research approach, and is not based on imagination or standardisation. An iterative design approach is currently being applied for upscaling.

Fig. 1a: The UI screenshot with markup



4.1. Description of the features embedded in the UI above

1. Text window: The pane that displays the transcribed speech of the teacher in text format.
2. Language drop-down menu: A hidden pane that contains a list of languages to allow users to select their preferred language for the text to be displayed
3. Connect and Disconnect buttons: To start or stop the live session.
4. Clear Transcript: To remove all the text from the transcript area (1), so the student can start fresh.
5. Toggle Auto Scroll: It enables automatic scrolling on or off, so the transcript either follows new speech or stays where the student is reading.
6. Download Transcript: It allows students to save a copy of the transcript to their device for later use or sharing.
7. Note Taking Pane: A dedicated space where students can write and manage their own notes during the session.
8. Save, Clear, and Download Notes buttons: They enable students to store their notes, erase or delete them, or download them as a file in their preferred format.

After the successful design of the first version of the UI and establishing the effectiveness of the system, we proceeded with implementing an iterative design to scale up the UI. The second stage of the user-discovery research was conducted with the same set of users, with the main purpose of identifying their pain points to optimise their satisfaction. Other new features our research discovered users would like to see in the UI are:

9. Time Stamp: To enable users to mark and navigate to a specific moment in the lecture process, and be able to reference or quote a precise segment easily.
10. Search Transcript: For fast keyword search across the transcript for easier review and analysis of the translated text.
11. Light / Dark Mode: To enable users to switch the visual theme of the interface to improve readability, comfort, and user preference customisation.

Figure 1b: The UI (light mode) after conducting the second stage of user-discovery research.

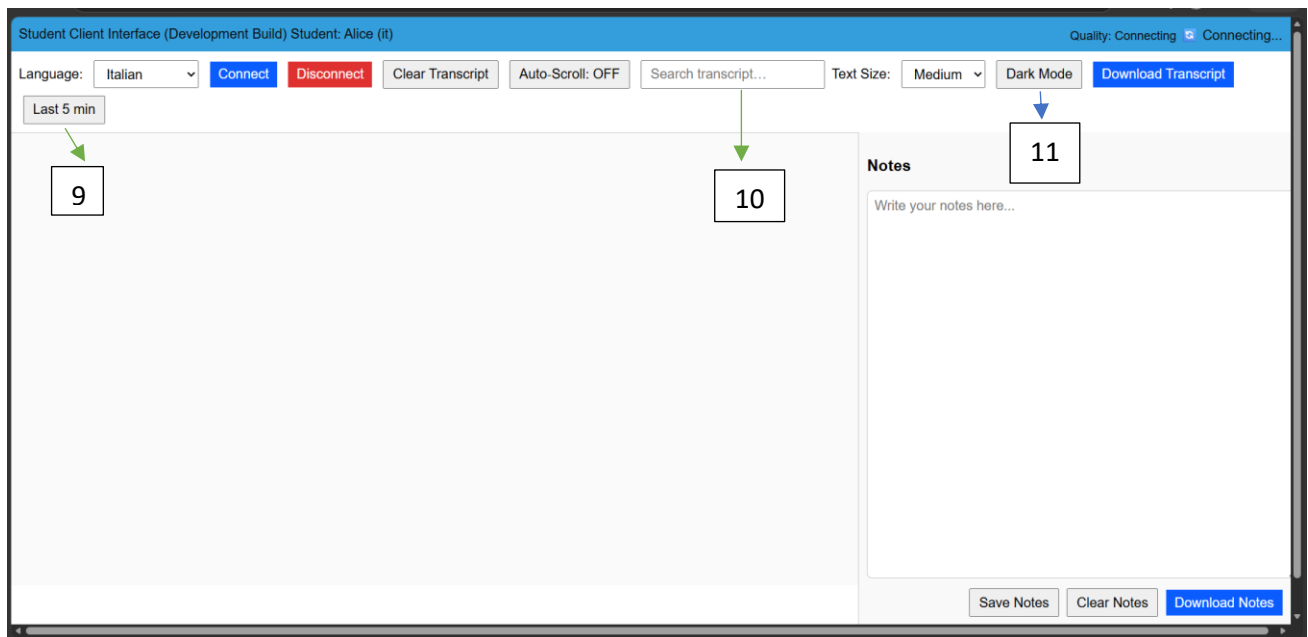
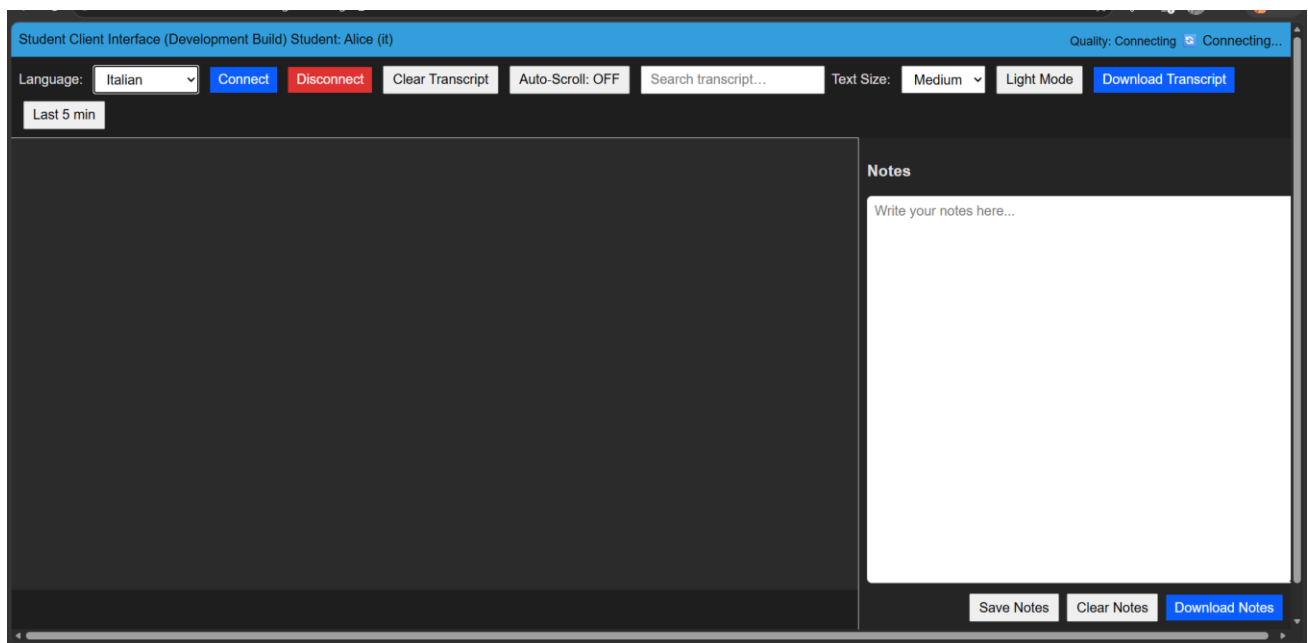


Figure 1c: UI (Dark mode)



5. Hierarchy of Usability Objectives

In our recent experience during the design of the user interface UI of the Adaptive Language Mediation System project, and the ongoing iterative design method, we perceived the importance of measuring the dimensions/components of usability from an objective perspective to order their priority and importance. That is, according to how important and impactful each of those components is to usability assessment and scaling.

The most important matter for any interactive system is that it enables the user to complete a defined task and or reach their defined goals; other than these, nothing else matters. Therefore, the Effectiveness of the interactive system becomes the priority. After this, Learnability becomes imperative early in design to optimise user experience, which is critical to avoid drop-off, frustration, and abandonment of the system. New users should be able to understand the interface structure with ease and start using the system successfully without significant learning challenges. In this sense, learnability acts as the gateway to all other usability components (Nielsen, 1993; Saad Subir & Hussah AlEisa, 2016). Efficiency matters only after users are familiar (experienced users) with the interface and want to work faster, but users must first learn the system before they can become efficient. Memorability deals with how users can return after a long break and still be able to use the system effectively. Satisfaction runs across all stages, reflection overall user experience.

Therefore, as designers in human-computer interaction (HCI) in education, we can practically order the priority of the dimensions by asking the following questions, as related to each dimension:

- i. **Effectiveness**- Can users complete tasks correctly using the system?
- ii. **Learnability**- Can users learn or figure out how to use this system quickly and easily without looking for help?
- iii. **Efficiency**- can the user achieve their goals with a minimal and within a reasonable amount of effort?
- iv. **Memorability**- How well can users remember the navigation patterns of the system later? -This dimension becomes important for a system that is not used daily.
- v. **Satisfaction**- Do users feel good using our system?

The questions outlined above can be measured numerically and by capturing users' experience insights. Effectiveness and Efficiency are usually quantified by measuring time-on-task and task success rate. Meanwhile, qualitative methods such as feedback, interviews, and observations can be used to assess Satisfaction, Learnability, and Memorability. Since usability is context-dependent, trade-offs are inevitable during the design process, and making the right trade-off decision depends on the ability to set priorities among the components (Alan Dix et al., 2004; Sommerville, 2016)

6. Methods for Usability Evaluation

Usability can be evaluated through multiple complementary methods, including Empirical Methods and Inspection Methods (Dehghani Mahmoodabadi et al., 2025)

- **Quantitative approaches**: - This approach focuses on performance metrics such as task completion rates, time on task, and error frequency. These methods provide objective, comparable data.
- **Qualitative approaches** include think-aloud protocols, interviews, and observational studies, which offer insight into user reasoning, difficulties, and perceptions.

The two approaches above are referred to as empirical methods because it involves real users.

- **Inspection methods**, such as heuristic evaluation and cognitive walkthroughs, allow designers and experts to identify usability issues based on established principles without requiring end users.

We recommend a mixed-methods approach as it combines the strengths of these techniques and mitigates their individual limitations.

7. Discussion

Based on the experience described and presented above, we present the conceptualisation of usability of interactive systems in education as a layered construct comprising user experience, interaction-level usability, and learning effectiveness. Measuring the usability of interactive systems presents several challenges. Fundamental to how usability is understood in Human-Computer Interaction, usability is context-dependent; assessing the usability of a system largely depends on who is using it, what they are trying to do with it, and under what conditions. Context matters because a system that works perfectly in one situation may fail badly in another due to any of the following reasons: user differences, task differences, device and platform, and environment.

Also, because usability should be context-based, trade-offs are inevitable. In that sense, design decisions will always improve one aspect of usability at the expense of another—for example, reducing interface complexity may limit functionality. Also, introducing desirable or required difficulty may enhance learning but reduce perceived ease of use, thus reducing satisfaction. Components where trade-offs usually show up include simplicity vs functionality, efficiency vs learnability. Therefore, making the right trade-off decision depends on priorities and how components are ordered in design. Doing this right requires insights into user experience, which can be acquired through user-discovery research.

8. Conclusion

User-discovery research is valuable because the goal is to understand real users' needs and behavioural patterns early in design. While quantitative indicators help us to understand how severe the problems are, the user-discovery approach gives designers qualitative insights that support a clear-cut understanding of the cause(s) of the problems and how to make informed trade-off decisions. A rigorous demonstration of usability, therefore, depends on integrating quantitative and qualitative methods within a coherent evaluation framework. Together, this mixed method bridges exploratory research and measurable evaluation to ensure that an interactive system is designed solely based on users' needs and can later be assessed and scaled with evidence-based criteria. Good design starts by understanding the real-world situation in which the system will be used.

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