

# Enhancing Feedback Uptake and Self-Regulated Learning in Procedural Skills Training: Design and Evaluation of a Learning Analytics Dashboard

Ignacio Villagrán<sup>1,2</sup>, Rocio Hernández<sup>3</sup>, Gregory Schuit<sup>4</sup>, Andrés Neyem<sup>5,6</sup>, Javiera Fuentes<sup>7,8</sup>, Loreto Larrondo<sup>9</sup>, Elisa Margozzini<sup>10</sup>, María T. Hurtado<sup>11</sup>, Zoe Iriarte<sup>12</sup>, Constanza Miranda<sup>13</sup>, Julián Varas<sup>14</sup> and Isabel Hilliger<sup>15</sup>

## Abstract

Remote technology has been widely incorporated into health professions education. For procedural skills training, effective feedback and reflection processes are required. Consequently, supporting a self-regulated learning (SRL) approach with learning analytics dashboards (LADs) has proven beneficial in online environments. Despite the potential of LADs, understanding their design to enhance SRL and provide useful feedback remains a significant challenge. Focusing on LAD design, implementation, and evaluation, the study followed a mixed-methods two-phase design-based research approach. The study used a triangulation methodology of qualitative interviews and SRL and sensemaking questionnaires to comprehensively understand the LAD's effectiveness and student SRL and feedback uptake strategies during remote procedural skills training. Initial findings revealed the value students placed on performance visualization and peer comparison despite some challenges in LAD design and usability. The study also identified the prominent adoption of SRL strategies such as help-seeking, elaboration, and strategic planning. Sensemaking results showed the value of personalized performance metrics and planning resources in the LAD and recommendations to improve reflection and feedback uptake. Subsequent findings suggested that SRL levels significantly predicted the levels of sensemaking. The students valued the LAD as a tool for supporting feedback uptake and strategic planning, demonstrating the potential for enhancing procedural skills learning.

## Notes for Practice

- The development of learning analytics dashboards (LADs) should consider theoretical aspects during all its design stages to effectively support feedback uptake and self-regulated strategies for procedural skills training.
- A structured design-based research approach allows us to consider both theory and student feedback throughout the development process of a learning analytics dashboard to support feedback uptake and self-regulated learning in health professions education.
- To incorporate a learning analytics dashboard in remote procedural skills training, special attention must be paid to students' prior self-regulated capacities and sensemaking, as well as the perceived usefulness of specific indicators and dashboard features.

**Keywords:** Learning analytics dashboard, feedback, procedural skills, self-regulated learning, health professions education

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<sup>1</sup> Email: [invillagran@uc.cl](mailto:invillagran@uc.cl) Address: Health Science Department, Pontificia Universidad Católica de Chile, 7820436, Santiago, Chile. ORCID iD: <https://orcid.org/0000-0003-3130-8326>

<sup>2</sup> Address: Computer Science Department, School of Engineering, Pontificia Universidad Católica de Chile, 7820436, Santiago, Chile.

<sup>3</sup> Email: [rbhernandez@uc.cl](mailto:rbhernandez@uc.cl) Address: Computer Science Department, School of Engineering, Pontificia Universidad Católica de Chile, 7820436, Santiago, Chile. ORCID iD: <https://orcid.org/0000-0003-4677-2519>

<sup>4</sup> Email: [gkschuit@uc.cl](mailto:gkschuit@uc.cl) Address: Computer Science Department, School of Engineering, Pontificia Universidad Católica de Chile, 7820436, Santiago, Chile. ORCID iD: <https://orcid.org/0000-0002-7219-9915>

<sup>5</sup> Email: [aneyem@ing.puc.cl](mailto:aneyem@ing.puc.cl) Address: Department of Computer Science, Pontificia Universidad Católica de Chile, 7820436, Santiago, Chile. ORCID iD: <https://orcid.org/0000-0002-5734-722X>

<sup>6</sup> Address: National Center for Artificial Intelligence (CENIA), Pontificia Universidad Católica de Chile, Santiago, Chile.

<sup>7</sup>Email: [ifuentesi@uc.cl](mailto:ifuentesi@uc.cl) Address: Health Science Department, Pontificia Universidad Católica de Chile, 7820436, Santiago, Chile. ORCID iD: <https://orcid.org/0000-0003-0720-2169>

<sup>8</sup>Address: School of Health Professions Education, Maastricht University, Maastricht, the Netherlands.

<sup>9</sup>Email: [lorelarrondov@uc.cl](mailto:lorelarrondov@uc.cl) Address: Health Science Department, Pontificia Universidad Católica de Chile, 7820436, Santiago, Chile. ORCID iD: <https://orcid.org/0009-0008-1617-3228>

<sup>10</sup>Email: [elisa.margozzini@uc.cl](mailto:elisa.margozzini@uc.cl) Address: Health Science Department, Pontificia Universidad Católica de Chile, 7820436, Santiago, Chile. ORCID iD: <https://orcid.org/0009-0004-9905-5964>

<sup>11</sup>Email: [t.hurtado@uc.cl](mailto:t.hurtado@uc.cl) Address: Health Science Department, Pontificia Universidad Católica de Chile, 7820436, Santiago, Chile. ORCID iD: <https://orcid.org/0009-0002-9560-1345>

<sup>12</sup>Email: [ziriarte@uc.cl](mailto:ziriarte@uc.cl) Address: Health Science Department, Pontificia Universidad Católica de Chile, 7820436, Santiago, Chile. ORCID iD: <https://orcid.org/0009-0000-6778-8048>

<sup>13</sup>Email: [constanzamiranda@jhu.edu](mailto:constanzamiranda@jhu.edu) Address: Department of Biomedical Engineering, Johns Hopkins University, Baltimore, USA. ORCID iD: <https://orcid.org/0000-0002-9110-2832>

<sup>14</sup>Email: [jevaras@uc.cl](mailto:jevaras@uc.cl) Address: Department of Digestive Surgery, Pontificia Universidad Católica de Chile, 7820436, Santiago, Chile. ORCID iD: <https://orcid.org/0000-0002-5828-9623>

Corresponding author <sup>15</sup>Email: [ihillige@uc.cl](mailto:ihillige@uc.cl) Address: Engineering Education Unit, School of Engineering, Pontificia Universidad Católica de Chile, Vicuña Mackenna 4860, Macul, 7820436, Santiago, Chile. ORCID iD: <https://orcid.org/0000-0001-5270-7655>

## 1. Introduction

The COVID-19 pandemic made technology-mediated teaching the primary strategy globally (Etoom et al., 2023). In health professions education, the procedural domain, which refers to the psychomotor abilities needed to perform various healthcare techniques, such as laparoscopy, manual therapy, and venous punctures, was the most difficult to adapt. Remote training ensured continued skill development during the pandemic. One remote strategy consisted of video simulations of a procedure and asynchronous feedback via a web-based platform. Among others, this approach effectively enhanced clinical skills acquisition for laparoscopy (Gaete et al., 2023), physiotherapy techniques (Villagran et al., 2023), and critical care (Vera et al., 2021).

With the emergence of new learning opportunities in procedural skills training, the students faced a challenge. They needed to acquire new skills to effectively utilize these strategies. Self-regulated learning (SRL) is critical to student success (Zimmerman, 2002). As clinical procedures are sequential, reinforcing SRL during skill training supports students in reflecting on and improving on their performance (Kitsantas et al., 2004). Specifically, SRL strategies play a relevant role in the long-term performance of procedural abilities (Brydges et al., 2012; Süß-Havemann et al., 2020), which is essential for in situ skills demonstration and optimal performance over time. Furthermore, SRL strategies help students to incorporate external feedback during deliberate practice and compare performance with expected standards (Wang et al., 2020; Brydges et al., 2012; Kitsantas et al., 2004; Nicol & Macfarlane-Dick, 2006).

Fortunately, the increased adoption of remote learning technologies during the pandemic presented an opportunity to leverage these technologies to imbue students with SRL strategies during procedural skills training. In that context, learning analytics dashboards (LADs) have stood out as a form of feedback that seeks to empower students and improve their SRL strategies as they progress in their learning process (Nicol & Macfarlane-Dick, 2006; Jivet et al., 2020; Wang & Han, 2021).

This study presents the design, implementation, and evaluation of a LAD to support SRL in the training of a healthcare procedural skill. According to Schwendimann et al. (2017), learning dashboards provide a single display that aggregates different indicators about learner(s), learning process(es), and/or learning context(s) into one or multiple visualizations. In this study, the LAD development followed a design-based research approach consisting of two phases: 1) tool design and testing and 2) broader implementation and evaluation. Further background information regarding technology-mediated feedback, SRL, and LAD development is presented in the subsequent sections.

### 1.1. Procedural Skills Training and Technology-Mediated Feedback

Technology is being considered an integral part of feedback processes in higher education (Deeley, 2018; Wood, 2021). Institutions use learning management systems (LMSs) to enhance interaction and active learning (Wood, 2021), providing an opportunity for improved feedback uptake. In technology-mediated learning, feedback is defined as “a process, not an input, that regulates a system, necessarily influencing the output of that system” (Dawson et al., 2018, p. 3). This definition emphasizes that feedback is not effective if it does not generate a change, so simply providing students with a comment or an audio commentary on their performance does not necessarily constitute feedback. Studies support the use of technology to manage practical aspects of feedback (Dawson et al., 2018; Deeley, 2018; Wood, 2021). It fosters students’ active role and continuous review and improves participation, feedback acceptance, and feedback literacy (Carless & Boud, 2018; Dawson et al., 2018).

In procedural skills training, technology could enable the continuous presentation of new opportunities for students to demonstrate that they have incorporated feedback, fulfilling the process goals. The psychomotor nature of procedural skills training requires learning activities to practice, repeat, reflect, and improve. Along these lines, technology has become a promising way to create opportunities for students to perform clinical procedures safely and efficiently.

However, the availability of feedback-oriented platforms is not enough on its own. To ensure that technology enhances learning, it is necessary to adopt a theoretical approach that supports SRL (Nussbaumer et al., 2015). Furthermore, feedback and SRL are intertwined since feedback is a vital component of the SRL phases (Jivet et al., 2020; Matcha et al., 2020). This is why it is essential to support SRL and feedback uptake, particularly when performing a procedural skill that requires mastering the technical aspects of a clinical task (Cecilio-Fernandes et al., 2023).

### 1.2. Self-Regulated Learning for Procedural Skills Training

To explore SRL processes by individual students across different clinical procedural skill tasks, it is crucial to understand the theoretical models of SRL. So far, different models coexist in the literature, where the most cited are Zimmerman (2000) and Pintrich (2000; Panadero, 2017). Zimmerman defines SRL as “self-generated thoughts, feelings, and actions that are planned and cyclically adapted to attaining personal goals” (Zimmerman, 2000, p. 14), while Pintrich places particular emphasis on metacognition, describing SRL as “an active, constructive process whereby learners set goals for their learning and then attempt to monitor, regulate, and control their cognition, intentions, and behavior, guided and constrained by their goals and the contextual features of the environment” (Pintrich, 2000, p. 453). With the interest of considering both motivational and cognitive factors, Winne and Hadwin (1998) proposed a model that puts the student in an active role in their learning (Panadero, 2017; Matcha et al., 2020; Greene & Azevedo, 2007), which has been widely used in computer-supported learning contexts.

Moreover, Winne and Hadwin (1998) highlight that feedback can occur intentionally when the students compare themselves with a standard. In this context, learning analytics solutions could inform student self-evaluation, thereby promoting a virtuous cyclical process that improves their performance based on feedback (Lim et al., 2021).

However, the best learning analytics methods for enhancing SRL remain unclear (Heikkinen et al., 2023). Although the literature indicates that SRL is a focus of LADs, Matcha et al. (2020), through a systematic review, identified a series of limitations in the relationship between LADs and SRL. Considering limitations applicable to procedural learning, current LADs struggle with effective feedback paradigms, often being unidirectional rather than dialogic, limiting students from fully embracing their learning towards an SRL experience (Matcha et al., 2020). More research is required to understand how LADs can provide applicable and actionable information to improve student learning experiences (Matcha et al., 2020).

### 1.3. Learning Analytics Dashboards (LADs)

LADs utilize data to provide visual feedback of the student progress, enhancing SRL by allowing self-assessment and performance improvement (Wang & Han, 2021). Those in charge of designing LADs identify learning data and encode it into indicators, graphs, numbers, colours, or text, which are then decoded by students, who put the information in context, evaluate it, and use it to make decisions. This process, on the part of the student, is known as sensemaking (Jivet et al., 2020).

LADs have received particular attention as tools to promote reflection and optimize learning and the quality of the learner experience (Matcha et al., 2020), becoming a common intervention to support SRL (Heikkinen et al., 2023). However, implementation alone is insufficient (Heikkinen et al., 2023), so more theoretical emphasis needs to be placed on how LADs are designed (Heikkinen et al., 2023; Sedrakyan et al., 2020; Matcha et al., 2020).

To meet these needs, the literature describes recommendations to support the development of a learning analytics-based solution to improve student SRL strategies with a focus on feedback. First, LAD prototypes should follow a framework, like the Model for User-centred Learning Analytics Systems (MULAS), which considers four dimensions, including theory, design, feedback, and evaluation (Matcha et al., 2020). Second, the process should prioritize feedback uptake, not just its provision (Jivet et al., 2020; Matcha et al., 2020). Third, understanding student sensemaking of feedback for SRL decisions is key (Lim et al., 2021). Finally, evaluations of student sensemaking of LAD indicators in relation to SRL strategies are needed (Jivet et al., 2020). This study employs a design-based research approach to develop a LAD, aiming to support SRL strategies and facilitate feedback uptake during procedural skills training for physiotherapy students.

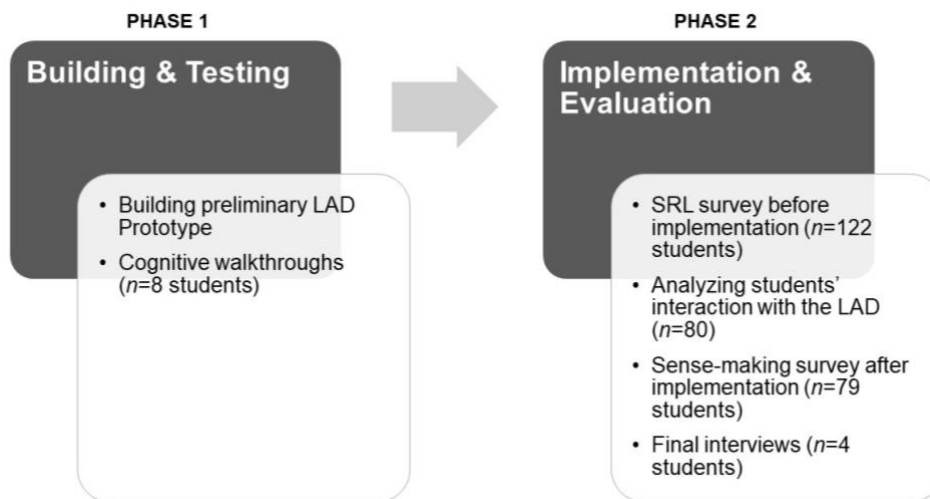
## 2. Research Question, Study Design, and Context

This study addresses the following research questions:

1. What indicators do students look for in a learning analytics dashboard for improving their self-regulated learning during procedural skills training?
2. How does the learning analytics dashboard support the feedback uptake and self-regulation strategies from the student perspective?

To answer these research questions, a design-based research (DBR) approach was followed. DBR is an iterative process to solve practical problems and improve learning outcomes through a series of interventions grounded in learning theories (Reimann, 2013). This process was organized into two phases using mixed methods (see Figure 1). The first phase involved the design and development of the LAD prototype. This step included pilot iterations to gather user feedback, which informed subsequent improvements to the prototype. The second phase consisted of a broader implementation and evaluation phase,

collecting information from surveys, logs, and final interviews. Each phase is presented according to the data collected and their analysis, as shown in Figure 1. Finally, a discussion was conducted with reference to the MULAS (Matcha et al., 2020).



**Figure 1.** Design-based research approach to develop the LAD

The study was implemented in a physiotherapy degree offered at a large, selective Latin American university. This degree program spans ten semesters with a combination of science- and practice-based courses to gain health sciences knowledge and develop skills for clinical practice. Specifically, this study took place during the second semester of 2022, and students in their sixth and eighth semesters were invited to voluntarily participate. All students were given an informed consent form approved by the corresponding ethics committee (ID: 220506007). These students were enrolled in clinical courses that employed a feedback-oriented platform to train some procedural skills with remote and asynchronous feedback, where the LAD was incorporated (see Appendix A). As part of the teaching strategy, students recorded themselves performing a procedure, uploaded this video to the feedback-oriented platform, and received an assessment from instructors who also provided feedback through inputs on the video (e.g., drawings, audio, and written comments). Students then received and reviewed the feedback directly within the video (Villagran et al., 2023). The training is structured in stages, with students receiving instructor feedback between each stage that they must incorporate in subsequent stages. The LAD was developed to complement this platform during the training of procedural skills. The methodology, results, and lessons learned in each phase are explained separately below, considering qualitative and quantitative aspects.

### 3. Phase I: Design and Development

#### 3.1. Preliminary LAD prototype

The LAD prototype consisted of two views: the main one and a secondary one. The main view is divided into seven sections (see Figures 2 and 3), each displaying indicators based on SRL strategies for remote learning (Appendix B) as reported in the literature (Kizilcec et al., 2017). The secondary view (see Figure 4) displays a collaborative forum where students can post comments through a text box.

In the main view, there is a selector to choose the course for which you want to review the information, which updates the data displayed in each one of its seven sections. To support student self-evaluation and goal setting, the first section provides the students with their overall level of achievement in the course selected. It also presents a percentage of skill attainment and their rank compared to the course in terms of percentiles, both on average and per stage (see Figure 2A). Then, the second section shows the scores of specific items that are part of the procedural assessment instrument used for every training stage so students can see which items have the highest scores (and which ones have lower scores). Additionally, the course average score for each item is represented in a different colour (see Figure 2B). To complement these indicators, the third section displays student performance situated within a learning curve that considers all stages of their procedural skills training so they can easily visualize whether their performance has improved throughout their learning process (see Figure 2C).

To support strategic planning of their next stage deliverable, the fourth section provides learners with information regarding course stages and deadlines (see Figure 3D). This is complemented by the fifth section, which shows all the text feedback inputs in a carousel form for each stage with the intention that students can switch between stages and compare the feedback provided in a single view (see Figure 3E). This differs from the feedback-oriented platform used in their training, where students can only review feedback one stage at a time, which is time-consuming and possibly limiting of student

ability to fully understand all the feedback. The sixth section was created so that, after reviewing the feedback, students could watch the video tutorial demonstrating what they had to deliver in the next stage (see Figure 3F). Finally, the seventh section was designed for students to close the feedback loop by reflecting on and recording in a self-evaluation box how they used the feedback received (see Figure 3G).

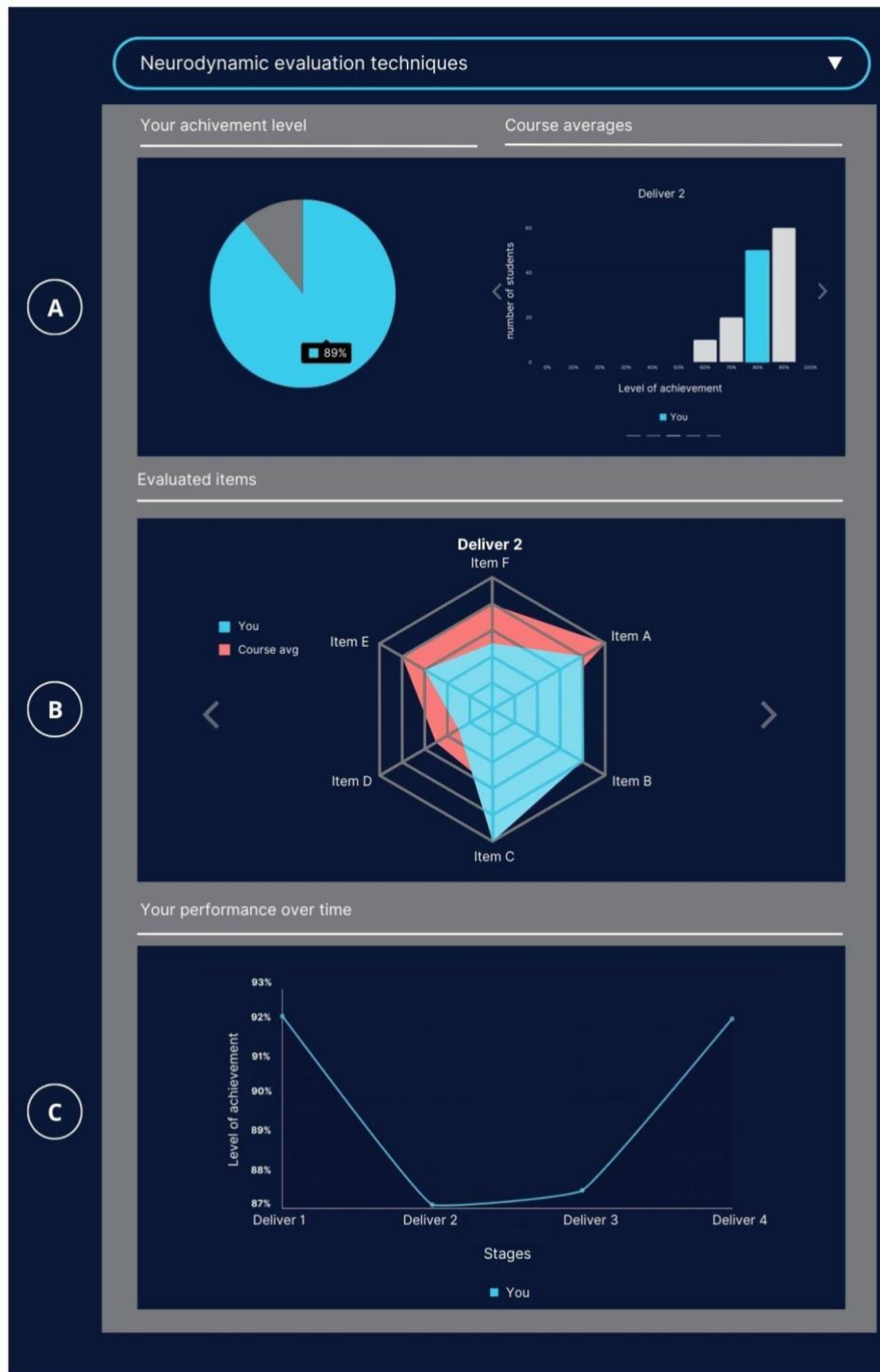


Figure 2. LAD first prototype sections (Part I).

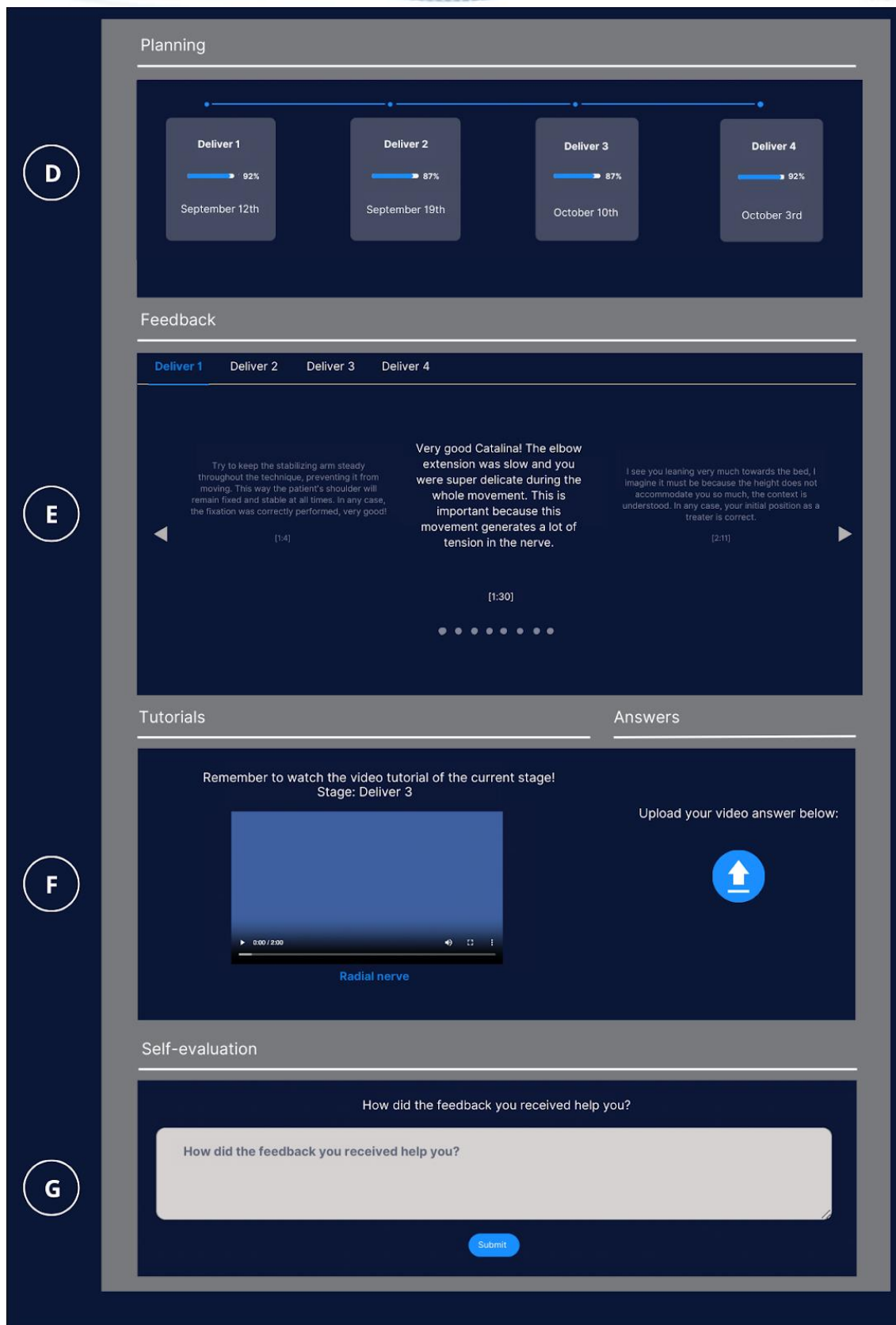


Figure 3. LAD first prototype sections (Part II).

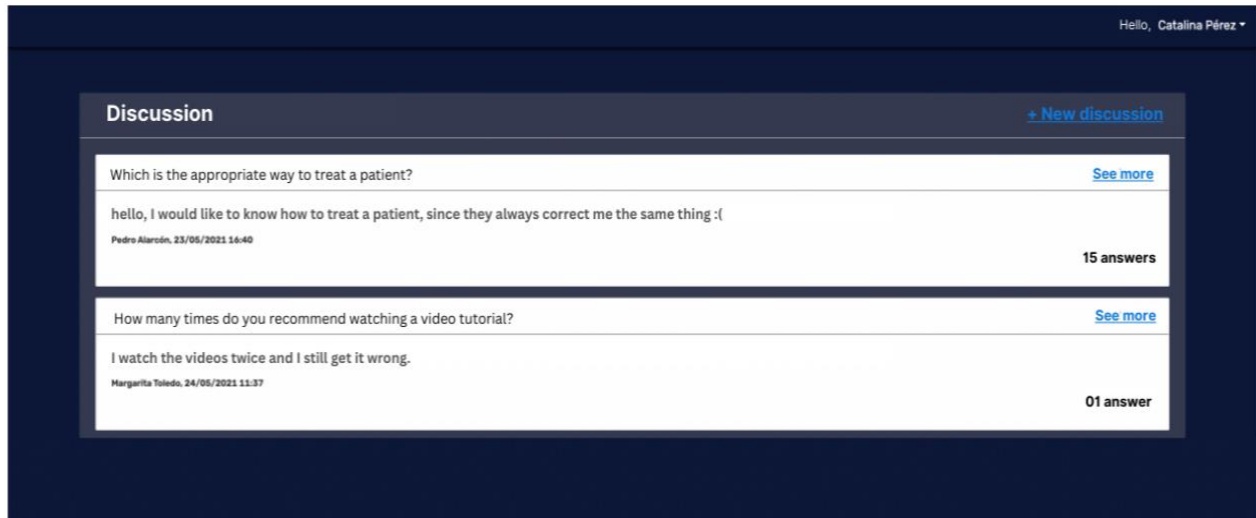


Figure 4. LAD's first prototype collaborative forum (Part III).

### 3.2. Phase I: Data Collection, Participants, and Analysis Plan

Considering that the visual attractiveness and usability of the dashboard could significantly affect potential behavioural changes (Park & Jo, 2019), the level of understanding and perceived usefulness was tested. We chose to employ cognitive walkthroughs as they have been effectively used in prior LAD testing (Chatti et al., 2020; Vigentini et al., 2017). This usability assessment technique engages participants as they try to complete tasks using the think-aloud methods, in addition to asking them questions about the difficulties that might arise from their interaction with the user interface (Wharton et al., 1994; Rieman et al., 1995). The cognitive walkthroughs consisted of individual interviews with eight fourth-year physiotherapy students via videoconferencing. Based on Dishman (2003), we followed a protocol that included activities to be performed, observations, and questions to participants to be answered (Appendix C). The students navigated the LAD, answered questions, and shared their opinions. The cognitive walkthroughs were recorded and transcribed verbatim. Two trained researchers analyzed each transcript through content analysis (Mayring, 2019). First, each researcher made an inductive list of codes that were discussed to reach a consensus list. Codes were then organized into categories and used to analyze all the cognitive walkthroughs and as a framework to analyze Phase II.

### 3.3. Phase I: Results

Three main categories were identified in the qualitative analysis (Table 1). The first category refers to student interest in and relevance of the LAD's features. Students highlighted functionalities such as visualization of overall performance and performance by item and over time, as well as understanding how they are doing with respect to the course. During the cognitive walkthroughs, students made comments such as "I would still be interested in the course average, and if there is a stage that is more difficult for me, or is difficult for everyone or easier, I would like to know" (P2). They also made suggestions for improving the visualization of feedback inputs. While they appreciated having all inputs in one location, they found it challenging to understand the inputs without seeing them on the video, as pointed out by one comment: "I wouldn't know what part of my video the feedback is from" (P2). They also questioned the usefulness of the self-assessment mailbox: "The self-assessment is a good idea, but I don't think anyone would actually use it, I wouldn't fill it out" (P4).

The second category is associated with the LAD perceived usefulness, which includes statements of what use they would make of the presented features of the LAD. This category highlights the importance of seeing a simple learning curve to be able to reflect and improve over time, as pointed out by one participant: "The performance over time graph is a visual aid to help us realize that we can improve, if I'm at 87–89% let's improve, let's get to 90%" (P6). On the other hand, having the consolidated information of the stages and delivery dates was also noted as useful for better planning. Regarding feedback, students emphasize the importance of reflecting on the information provided through the inputs: "Many times you think you are doing well, but then you review the teacher's assessment, and you can contrast both views" (P6) and give meaning to a section for requesting and granting help: "Using the forum is something that is going to help all of us. I would be willing to respond to my peers" (P6).

The third category groups student comments regarding the global evaluation of the LAD in terms of usability, design, and suggestions. There is a significant group of opinions regarding the improvement of the colour structure: "It's very grey, so maybe it could be other colours. And I would enlarge the lettering a little bit because I had to get very close to the

computer” (P3). It is also highlighted that the LAD and most of the graphics are easy to navigate since they are all on the same page: “I find it useful and it’s all like what I need, I don’t need to keep changing windows” (P4). However, the item graph drew attention for the difficulties it posed in understanding and interpreting indicators, as one student noted: “I don’t really understand how to extract the information from the items graph” (P1).

**Table 1.** Results of the Qualitative Analysis of Phase 1 Interviews (*n*=8)

Category	Category description	Code	Code description	Number of coding references	Number of participants
Interest in LAD functionalities	This category refers to the student interest in and relevance of the LADs features, including the perceived usefulness and potential areas for improvement.	Visualization of feedback inputs	Relevance of viewing feedback on the LAD, offering an easier way to access and review feedback. However, direct links to student video-assessments on the platform are recommended.	9	6
		Social comparison	Perceived value of comparing individual performance with the course, internalizing their standing in terms of performance and areas of improvement.	7	5
		Visualizing performance progress	Visualization of student performance over time, highlighting importance of tracking progress and clarity of the visualization.	6	4
		Seeing video tutorials	Utility of video tutorials accessible through the LAD, being this feature user-friendly, despite also having videos on the main platform.	4	4
		Reviewing overall performance	Relevance of reviewing individual overall performance, highlighting visual display, and understanding where they are standing in the course.	3	3
		Reviewing performance per item	Relevance of item-specific performance evaluation. Appreciate having an easy-to-understand breakdown of their performance.	3	3
		Answering self-evaluation box:	Use of a self-evaluation box for self-reflection, reporting value in reflecting on their own but also doubts of propensity to use this feature.	6	6
LAD perceived usefulness	This category is associated with the perceived benefits and utilities of the LAD platform from the perspective of the participants,	Improving performance over time	How the LAD enables the students to track their performance progression over time and identify consistent issues for improvement.	7	6
		Planning study strategies	How LAD assists in visually planning their study strategies, keeping track of important dates, and organizing their progress.	9	5
		Learning collaboratively	Potential value of using LAD as a platform for collaborative learning, including forums for shared	5	4

Category	Category description	Code	Code description	Number of coding references	Number of participants
Overall LAD evaluation	including personal learning, improvement strategies, feedback utilization, planning, and collaborative learning experiences.		understanding and collective problem-solving.		
		Using feedback for future performance	How the feedback section in LAD helps students to reflect and improve for future performance.	4	2
		Knowing which items to improve	How LAD supports students to identify specific areas of improvement of their performance	3	2
		Knowing my level of achievement	Usefulness of viewing their overall performance level in the LAD.	1	1
	This category groups the user perceptions, experiences, and suggestions concerning the LAD, including usability, design, functionality, and potential enhancements of the LAD.	Challenges using the LAD	LAD perceived difficulties and misunderstandings, including graphs interpretations, finding specific information, and need for assistance.	13	6
		LAD design and appearance	Visual presentation of the LAD. Some participants found it pleasing while others suggested improvements like colour adjustments and text enlargement.	10	5
		LAD ease-of-use	How understandable and user-friendly the LAD is, including user feelings on the dashboard's simplicity, clarity, and convenience.	6	4
		Proposal of improvement	User suggestions for making the LAD better, including reorganizing elements, improving design, and several areas where the LAD could be more user-friendly and informative.	4	2

### 3.4. Lessons Learned from Phase I

Qualitative results not only reinforced the usefulness of specific indicators but also revealed key areas for prototype improvements. The functionalities of the dashboard considered useful by students were reviewing their overall performance, identifying specific areas for improvement, comparing with the course performance, tracking performance progression, planning study strategies, accessing feedback inputs conveniently, and promoting collaborative learning experiences. However, the primary areas identified for improvement included enhancing the visualization of feedback inputs linked to video assessments, addressing concerns about motivation for using the self-evaluation box, as well as comments regarding colour and text sizes, and the availability of timely instructions for LAD usage.

In response to these results, the prototype was modified based on the feedback received. First, in terms of LAD appearance, the size of the titles and the size of the legends of each graph were increased, and the grey background was removed. The radar graph from the second section was replaced with a new graph that shows students' best and lowest scores on the rubric items, as compared to the course average for each item (see Figure 4). This new representation provided a clearer view than the previous individual performance display. In the fourth section, the due date for each stage was incorporated into the boxes to enhance the possibility of planning their studies in relation to a deadline (see Figure 5). Also, a link was added to the fifth section, so students could go to the view of the feedback-oriented platform and see the video response and the comments simultaneously. Further changes were made to improve the experience and speed when extracting information from the visualizations.

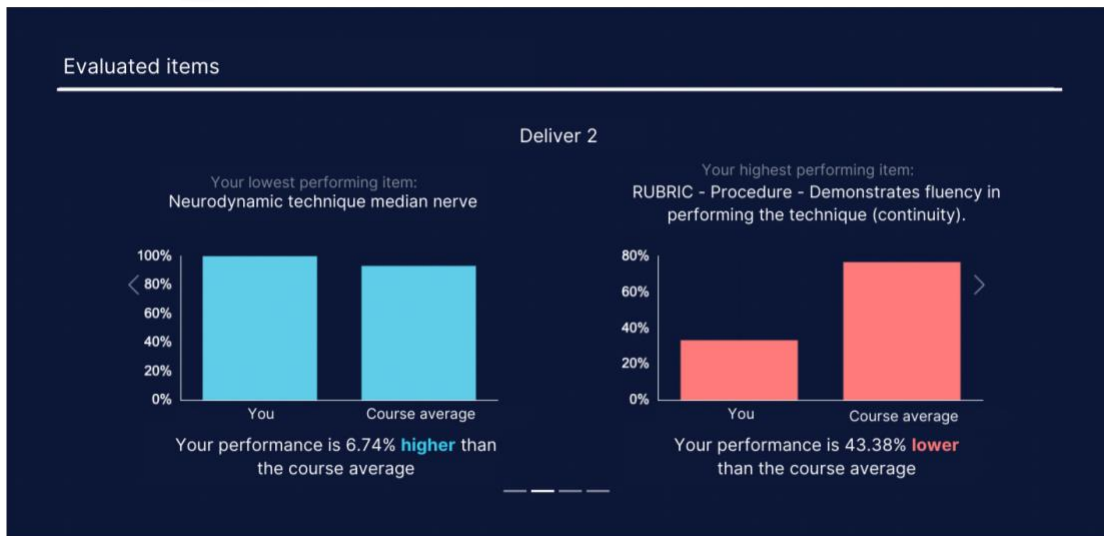


Figure 4. Visualization for evaluated items section.

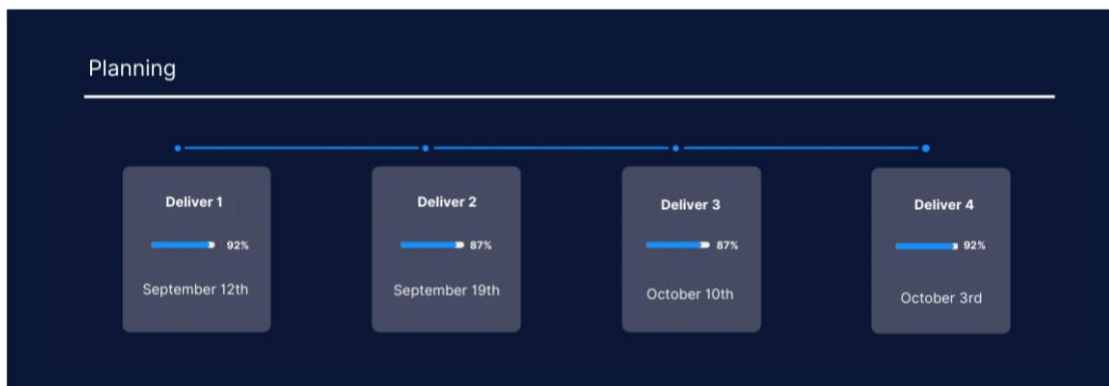


Figure 5. Planning section with the expected deadline.

## 4. Phase II: Broad Implementation and Evaluation

### 4.1. Phase II: Data Collection, Participants, and Analysis Plan

The improved version of the dashboard was implemented and evaluated for one month, aiming to study how a larger group of students interacted with the LAD. Prior to LAD implementation, the SRL-questionnaire was applied to 122 students to measure SRL strategies for online learning environments, as described by Kizilcec et al. (2017), aiming to determine student SRL strategies before using the LAD. Following implementation, a sensemaking survey based on the format of the scale proposed by Jivet et al. (2020), but adapted for the LAD indicators, was administered. Additionally, the number of students who logged on to the LAD, along with the number of visits by each, was obtained. Finally, open-ended interviews were conducted with students to understand how they perceived the use of the LAD in their decision-making process.

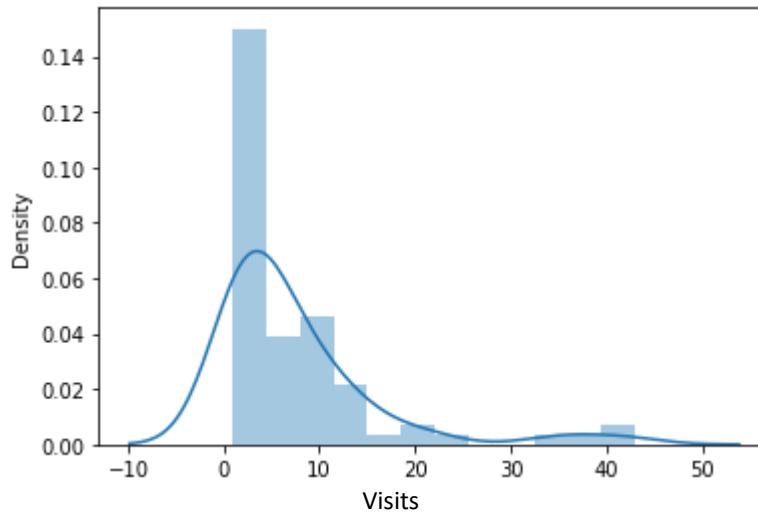
A descriptive analysis of the SRL-questionnaire and the sensemaking survey was performed. For the SRL survey, each dimension was analyzed in terms of its median and proportions and frequencies for each response option. For the sensemaking survey, each item was analyzed in terms of proportions and frequencies for each response option and also mean and standard deviation. To understand the importance students assigned to the LAD, it was analyzed whether the SRL strategies were related to students' level of sensemaking of LAD indicators through a multiple regression model, using sensemaking level as the dependent variable, SRL strategies as the predictor variable, and total number of dashboard visits as the covariate. All quantitative analyses were conducted using RStudio Software version 1.2 (2019, Boston, MA, USA). Finally, four final interviews were conducted with students during the second phase to understand their experiences after using the LAD. Interviewees were those students who voluntarily wanted to participate and who logged on to the dashboard. Interviews included usability questions guided by an initial cognitive walkthrough and other open-ended questions following the same protocol used in Phase 1 (Appendix C). Like Phase 1, interviews were recorded and transcribed verbatim, and then

results were inductively coded by two researchers. The three original categories and codes that emerged from the initial cognitive walkthroughs (Table 1) were utilized as a framework for the analysis, yet they did not restrict the creation of new codes or the elimination of existing ones.

**4.2. Phase II: Results**

**4.2.1. Number of Visits**

Out of the 122 students, 79 logged on to the dashboard, each making an average of 7.43 visits. Figure 6 shows a concentration of students between 1 and 10 visits, with 22 students (27.8%) visiting the dashboard ten or more times.



**Figure 6.** Distribution of student LAD visits.

**4.2.2. SRL Survey Before Implementation**

The SRL survey was applied before they used the LAD. This survey was chosen because it has already been used in remote and asynchronous learning environments. It consists of 24 items within a 5-point Likert scale that goes from “totally agree” (5) to “strongly disagree” (1). This scale has six dimensions: goal setting (GS), strategic planning (SP), task strategies (TS), elaboration (E), self-evaluation (SE), and help-seeking (HS).

The results of the descriptive analysis provided an overall picture of each student’s SRL profile (Table 2). The highest levels of agreement of students employing these strategies (combining “Agree” and “Totally Agree”) were seen in SP (71.1%), E (72.67%), and HS (76.83%), with the latter showing the highest rate of “Totally Agree” responses. The GS and TS dimensions also exhibited important levels of agreement, with 63.94% and 60.32%, respectively. The lowest level of agreement was found in SE (55.45%). Many students selected the neutral option, particularly for SE (30.6%) and GS (23.77%).

**Table 2.** Results of the First SRL Survey Applied to Physiotherapy Students (n=122)

Item	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Totally agree	Median (P25–P75)
GS	2.66% (13)	9.63% (47)	23.77% (116)	39.14% (191)	24.8% (121)	3.75 (3.25–4.44)
SP	2.46% (12)	7.17% (35)	19.26% (94)	34.63% (169)	36.47% (178)	4 (3.75–4.44)
TS	4.92% (36)	11.62% (85)	23.11% (169)	31.46% (230)	28.86% (211)	3.67 (3.17–4.17)
E	0% (0)	6.01% (22)	21.31% (78)	35.24% (129)	37.43% (137)	4 (3.67–4.67)
SE	2.18% (8)	11.74% (43)	30.6% (112)	32.78% (120)	22.67% (83)	3.67 (3–3.25)
HS	2.66% (13)	8.60% (42)	11.88% (58)	26.02% (32)	50.81% (62)	4.25 (4–4.75)

**4.2.3. Sensemaking Survey After Implementation**

At the end of the intervention, the students were asked to answer the sensemaking scale (Table 3) based on the prior work of Jivet et al. (2020). This scale consists of 14 items associated with the indicators of the LAD, with responses ranging from “extremely irrelevant” (1) to “extremely relevant” (10). Out of the 122 students, 79 students logged into the LAD and also answered the sensemaking scale, focusing on student perception and reception of each indicator presented in the LAD.

The results in Table 3 show that most students found personal performance indicators extremely relevant, including their overall course grade (74.7%), their performance relative to the maximum possible (74.7%), and their comparison to past performance (67.1%). Indicators related to performance overview and progress tracking were also deemed highly relevant, with 62.0% favouring a performance outline from the start of the course to current progress and 48.1% appreciating stages information. Recommendations for the following stages or topics to revisit were found extremely relevant by 64.6% of students. However, the sensemaking survey items related to comparisons with other students were less favourably received, particularly concerning the poorest-performing item (19.0% found it highly relevant) and the best-performing item (22.8%).

**Table 3.** Results of the Sensemaking Scale Applied to Physiotherapy Students After They Saw the LAD

Item	Extremely relevant	Not very relevant	Slightly relevant	Very relevant	Extremely relevant	Mean (SD)
(S1) See my overall course grade	0.0% (0)	0.0% (0)	5.1% (4)	20.3% (16)	74.7% (59)	4.70 (0,56)
(S2) See my performance in comparison to the maximum possible (100%)	0.0% (0)	0.0% (0)	7.6% (6)	17.7% (14)	74.7% (59)	4.67 (0,61)
(S3) See my performance in comparison to other students	3.8% (3)	8.9% (7)	29.1% (23)	30.4% (24)	27.8% (22)	3.70 (1,09)
(S4) See my performance compared to my past performance	0.0% (0)	1.3% (1)	7.6% (6)	24.1% (19)	67.1% (53)	4.57 (0,69)
(S5) To have an overview of my information from the beginning of the course to my current progress	0.0% (0)	1.3% (1)	6.3% (5)	30.4% (24)	62.0% (49)	4.53 (0,68)
(S6) Having my information displayed for each topic covered in the course	0.0% (0)	1.3% (1)	15.2% (12)	35.4% (28)	48.1% (38)	4.30 (0,77)
(S7) Have a consistent use of colours	1.3% (1)	5.1% (4)	12.7% (10)	31.6% (25)	49.4% (39)	4.23 (0,95)
(S8) Receive information to help me plan my learning (how to estimate the time needed)	2.5% (2)	3.8% (3)	10.1% (8)	32.9% (26)	50.6% (40)	4.25 (0,97)
(S9) Receive recommendations on which topics to cover in the next stage or which ones to revisit	0.0% (0)	1.3% (1)	10.1% (8)	24.1% (19)	64.6% (51)	4.52 (0,73)
(S10) Receive information on top performing items	1.3% (1)	5.1% (4)	17.7% (14)	35.4% (28)	40.5% (32)	4.09 (0,95)
(S11) Receive feedback on my best-performing item compared to other students	3.8% (3)	15.2% (12)	36.7% (29)	21.5% (17)	22.8% (18)	3.44 (1,12)
(S12) Receive feedback on the worst performing items	3.8% (3)	5.1% (4)	11.4% (9)	27.8% (22)	51.9% (41)	4.19 (1,08)
(S13) Receive feedback on my poorest performing item compared to other students	8.9% (7)	20.3% (16)	24.1% (19)	27.8% (22)	19.0% (15)	3.28 (1,24)
(S14) Watch the video tutorial of the next step	2.5% (2)	3.8% (3)	7.6% (6)	19.0% (15)	67.1% (53)	4.44 (0,97)

**4.2.4. Student SRL Strategies on LAD Sensemaking**

The effect of the level of SRL on sensemaking was analyzed through a multiple regression model (Table 4). It was identified that the level of SRL significantly predicts the relevance (sensemaking) given by the students to LAD indicators ( $p < 0.01$ ). This means that for each point of increase in SRL strategies, the relevance given to the dashboard indicators also increases by 0.29 points, controlling for the total number of logins to the platform.

**Table 4.** Multiple Linear Regression for the Sensemaking Variable with SRL Strategies and Number of LAD Visits (Total Visits) as Predictors

		<i>B</i>	<i>EE</i>	<i>t</i>	<i>p</i>
<i>Sensemaking</i>	Intercept	2.99	0.41	7.24	<0.001
	SRL	0.29	0.10	2.82	<0.01
	Total visits	0.02	0.01	1.68	0.09

**4.3. Students’ Final Interviews**

As a result of the four final interviews (Table 5), a new code was created, termed “Having direct links to the platform,” which was subsequently added to the “Interest in LAD functionalities” category.

**Table 5.** Results of the Qualitative Analysis of Phase 2 Interviews (n=4)

Category	Code	Number of coding references
Interest in LAD functionalities	Social Comparison	6
	Answering self-evaluation box	5
	Having direct links to the platform	4
	Visualizing performance progress	4
	Visualizing feedback inputs	4
	Seeing video tutorials	2
	Reviewing overall performance	2
	Reviewing performance per item	1
	Learning collaboratively	8
	Using feedback for future performance	8
LAD perceived usefulness	Planning study strategies	6
	Improving performance over time	5
	Knowing which items to improve	1
	Knowing my level of achievement	1
Overall LAD evaluation	LAD design and appearance	7
	Proposal for improvement	7
	Challenges using the LAD	7
	LAD ease-of-use	3

For the first category, the interest of reviewing the indicators associated with their overall performance, their performance over time, and comparing themselves with the course performance was confirmed: “*Comparing with the course average is very useful to know how well or poorly I am doing. Because sometimes you think you got a bad grade, but you’re actually above the majority of the course, and that’s not so bad in the end*” (P10). The self-assessment box had the same

mixed results as on Phase 1. Student comments were found that highlight that it is important to reflect on the feedback and how to use it, but that overall, they would not complete the box unless it was mandatory to do so. This does not diminish the importance of individual reflection and reinforces that feedback should be dialogic: *“For the self-evaluation mailbox, if I am asked to do it, I answer it, but not if I am not. But feedback is useful to me. I do my own reflection”* (P9), and *“I really feel that it is also important that the feedback is for both sides, because of course, if the teacher gives feedback on what I do, then I would also like to respond to that feedback and give my own reflection on it”* (P12). It is worth noting that student appreciation for feedback visualization improved, as they now had a direct access button to review their feedback within the platform’s video component. The above created a new category, “Having direct links to the platform,” which is defined as the “perceived usefulness of being able to directly access the platform to review instructional material of a stage and also the feedbacks incorporated in the video assessments.”

For the second category, the high interest in reflecting on their own performance progress is maintained. Also, the perceived usefulness of how LAD can support planning prior to delivery due dates. Regarding perceived value of feedback as a tool for improving future performance, interviewee opinions showed a better and clearer assessment of it, highlighting that it helps them to avoid making the same mistakes in similar future stages and clinical practice. *“It is very important to know what things to improve, what things not to do, what things to do more, what to emphasize more, so it really helps me a lot when the professors give me written feedback and I always have my own reflection”* (P12). One aspect that stood out in this category was the high appreciation of the community part of the LAD, highlighting its use for sharing tips and questions among peers.

For the third category, regarding the design and appearance, although the assessment of the design and the understanding of the general structure improved, opinions persist regarding the colours and their brightness. *“Regarding the design, I would put more white tones. Although the contrast is useful and not difficult to visualize, I would prefer lighter colours”* (P9). In terms of ease of use, it was noted that extended usage over time can enhance understanding of the LAD. Regarding the challenges, this time they are focused on making more visible the LAD features, needing short introductions or tutorials beforehand.

#### 4.4. Lessons Learned from Phase 2

The quantitative data from the SRL and sensemaking surveys demonstrated that a student’s level of SRL significantly predicts the relevance or sensemaking they attribute to the LAD indicators. This was supported by the results of the SRL survey, which showed that the HS dimension had the highest level of agreement while the SE dimension had the lowest. These results aligned with the final interview findings, which showed a high interest in the collaborative forum for help-seeking and low interest in the self-evaluation mailbox if it was not required.

Finally, the interviewed students highlighted three key factors that motivate them to use the LAD. First, the LAD indicators are simple to understand and allow for quick conclusions about their performance and feedback metrics. Second, the LAD visualizations streamline some interactions that are more time-consuming within the feedback-oriented platform, such as visualizing the feedback delivered by the teacher and specific information of a stage. Third, the LAD is more meaningful when used over an extended period, as it facilitates the observation of performance changes throughout the course.

## 5. Discussion and Future Directions

This study reports the results of a design-based research (DBR) approach employed to design, implement, and evaluate a LAD to support SRL in procedural skills training. The findings offer insights gleaned from incorporating theory and student perceptions to guide a two-phase DBR approach. The initial phase underscored the significance that students place on visualizing their overall performance in comparison to their peers, along with the capability to observe the evaluation of their performance throughout the training. While this phase did reveal students’ diminished motivation for the self-evaluation features of the LAD, it also demonstrated how providing students with a visualization of feedback inputs could enhance their uptake for learning improvement. Moreover, students appreciated having information to plan their training with a deadline in mind. All these lessons were learned in a context where usability and design challenges were still influencing the understanding and navigation of the LAD. In the second phase, most students reported adopting SRL strategies, particularly those of help-seeking behaviours, elaboration, and strategic planning. Furthermore, since the association between the use of more SRL strategies and the perceived relevance of LAD indicators (sensemaking) was statistically significant, students who report adopting a greater number of SRL strategies are more likely to perceive LAD indicators as relevant. This sentiment was echoed in the final interviews and sensemaking survey, with reported value not only in making sense of their performance learning curve but also in reflective practices, feedback uptake, and optimal planning for future training stages.

### 5.1. Evaluation of the Design and Implementation Process Using the MULAS Approach

Following the suggestions from various literature, a conceptual framework and a DBR approach were applied to guide the development of the LAD. Specifically, the MULAS model proposed by Matcha et al. (2020) was used, which suggests avoiding early design decisions and incorporating design cycles that address theory, design, feedback, and evaluation dimensions. By applying the MULAS approach, what was done well and what could be improved regarding different LAD aspects was determined.

(1) “Theory” guided LAD design to reinforce SRL and feedback uptake, acknowledging its influence on performance and learning curve in procedural skills training. Previous studies also helped to explain the physiotherapy students’ strategies regarding remote and asynchronous procedural skills training (Villagran et al., 2023).

(2) Concerning “Design”, a general scheme based on theory (i.e., Kizilcec’s approach to Pintrich theory) was used to guide the LAD prototype. Throughout the DBR approach, this was complemented with cognitive walkthroughs and qualitative interviews. Considering that both theory and user inputs informed the LAD design, complementing these two sources throughout the design process is suggested.

(3) “Feedback” is a central part throughout the various stages of the student learning curve. For this, a special focus was placed on how to support feedback uptake and what opportunities for improvement emerged. Traditionally, feedback has been understood as information delivered by the teacher or a peer to a student, who acts as a receiver. However, feedback should be understood as a two-way, student-centred process, with students playing an active role during their learning (Carless & Boud, 2018; Nash & Winstone, 2017). This study aimed to promote more efforts to encourage the two-way nature of feedback in procedural skills training, providing students with technology-mediated learning opportunities to improve their performance (i.e., feedback-oriented platform and an aligned LADs). In these lines, students valued having feedback inputs situated in a learning curve logic, reporting the importance of using the feedback to improve their performance through the stages of their procedural skills training.

(4) Finally, regarding “Evaluation”, MULAS stresses that evaluations of LADs should consider mixed-methods, experimental or correlational studies complemented by qualitative methods to identify the specific effects of LADs on learning outcomes. According to Creswell (2010), the nature of mixed methods can be expanded to include different applications, integrating its procedures into existing research designs. Along these lines, this study used mixed methods in a DBR approach, a type of study that is not commonly adopted for LAD design (Matcha et al., 2020). In that context, when learning analytics and learning design are well-aligned, personalized feedback could become meaningful, fostering uptake, and optimizing SRL strategies (Lim et al., 2021).

### 5.2. Using LAD to Support Feedback Uptake and SRL Strategies: What Do Students Say?

Concerning the use of the LAD, findings show that students value the fact that they are shown information about the stages and delivery times, reinforcing their strategic planning strategies. These findings are aligned with Schumacher and Ifenthaler (2018), who suggest that learning analytics tools should scaffold planning learning activities based on previous learning, recommendations, and self-assessment. Additionally, the SRL survey indicates that students are willing to use collaborative learning methods, which is further supported by the qualitative interviews where students expressed their interest in using LAD community features as a help-seeking strategy, not only for asking and answering questions of peers but also to guide future cohorts of trainees during their procedural skills training. In the final interviews, some students described feedback as a dialogic type of process, per the idea that feedback uptake and feedback literacy can be supported through student–teacher dialogues mediated by technology (Wood, 2021). Thus, results describe the learning benefits of a LAD to support strategic planning and help-seeking in the procedural domain, where students benefit from not only incorporating instructor feedback to perform a specific procedure but also from giving feedback to peers or senior students (Zhang et al., 2022; Villagran et al., 2023). These results go beyond previous studies in remote environments, such as the one led by Kizilcec et al. (2017), where different sources of evidence indicated that students did not incorporate help-seeking behaviours, including lowest scores in the “Help Seeking” dimension of their SRL scale, along with little participation in MOOC discussion forums.

The results of the sensemaking survey, cognitive walkthroughs, and final interviews indicate that students value personalized performance metrics and planning resources in the LAD to help them understand their personal learning progression and achievements. Additionally, students also found highly relevant feedback inputs as recommendations on which topics to study next. Conversely, performance comparison with other students had one of the lowest relevance scores, which may suggest that students are more focused on their procedural skills progress rather than on their peers’ performance. Lim et al. (2019) describe a similar phenomenon for sensemaking and attribute this behaviour to possible social anxiety that may be triggered when participants see that peers are doing better.

Still, the LAD may need further improvements to support SE and GS strategies. In this regard, Schumacher and Ifenthaler (2018) determined that student expectations of learning analytics features are centred on planning and organization of their learning process by means of self-assessments, adaptive recommendations, and personalized analyses of their learning activities. During the qualitative interviews of this study, students revealed a sort of rejection towards the self-evaluation LAD feature, which consisted of a box to write their reflections upon feedback. However, the participants assured

that they usually self-reflect; they just did not find the motivation to register it in a LAD. Moreover, the high rate of neutral responses in several categories within the SRL survey, especially in SE and GS, suggests that some students may be uncertain about using these strategies during their skill development process. In other words, they value having indicators regarding their performance, but they do not necessarily know how to act upon that feedback to improve their learning. This means that there are still plenty of opportunities for both instructors and LAD developers to provide students with LAD resources and clearer guidance about the incorporation of SRL strategies in their studies.

### 5.3. Conclusions and Limitations

This study focuses on the development and application of a LAD aimed at supporting students in SRL strategies, feedback uptake, and procedural skills training. Improvements to the LAD prototype were made via a two-phase DBR approach, identifying student adoption of SRL strategies and their understanding of the LAD indicators. The MULAS assessment tool was used to evaluate the effectiveness of addressing literature-identified gaps in the development process.

This study is not exempt from limitations. First, concerning the login frequency reported in our research, determining its appropriateness is challenging due to the variability in study contexts that may influence the number of visits (Kim et al., 2016; Park & Jo, 2019). Nevertheless, it has been recognized as a pertinent metric, directly correlating with other variables. Kim et al. (2016) analyzed how often each student accessed the LAD during its assessment process, demonstrating that this indicator is directly related to satisfaction with the LAD. Interestingly, some LADs initially draw interest but eventually lead to reduced motivation and fewer visits. Moreover, existing literature suggests that various indicators, such as weekly logins, the number of accessed learning resources, participation records in platform activities, along with factors like student characteristics and LAD usage patterns, could reflect student engagement levels. These indicators are not only for educators but also provide additional feedback for students within the LAD (Rets et al., 2021; Susnjak et al., 2022). Although the frequency of login to the LAD was measured in this study, further research, including new variables such as personal characteristics and other online learning indicators, may help to better explain user behaviour and engagement. A significant challenge is integrating the LAD in a manner that students find practical and relevant, encouraging more frequent use. In our study, students needed to access the LAD on a separate webpage than the feedback-oriented platform, causing extra effort to enter the LAD. In the final interviews, students confirmed this as one of the reasons for not interacting further with the LAD. Future work will focus on integrating the LAD into the feedback-oriented platform, potentially improving interaction rates (Roco, 2015). Second, although the LAD was a useful tool for self-regulated learners, aiding in their strategic planning, performance tracking, and study planning, it could not be verified that students with lower SRL found the LAD indicators relevant so they can improve their SRL strategies. This correlation could guide learning platform designs aiming to support student sensemaking during its use (Lim et al., 2019).

Still, this study expands the current understanding of how LADs can enhance remote learning for health professions trainees by supplementing the feedback process. Future improvements to the LAD could include diversifying its features, incorporating AI, and ensuring continuous student engagement. This could help keep the tool up to date with technologies used in areas such as learning analytics or educational data mining.

### Declaration of Conflicting Interest

Julian Varas is the Founder of Training Competence, an official spinoff startup from the Pontificia Universidad Católica de Chile. The startup and the Pontificia Universidad Católica de Chile are the owners of the rights and distribution of the feedback-oriented platform used to populate the dashboard. The rest of the authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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## Appendices

### Appendix A. Clinical Courses Selected for the Study

Curricular level	Course	Main objectives
Sixth semester	Musculoskeletal assessment	To develop and apply appropriate techniques for musculoskeletal assessment across various health conditions and analyze the results through clinical reasoning.
	Cardiorespiratory assessment	To perform and interpret key clinical assessment tests for both adult and pediatric cardiovascular and respiratory systems, while developing clinical reasoning skills to identify patient-specific problems.
	Neurological assessment	To assess pediatric and adult patients with neurological conditions, formulating a process and employing suitable evaluation strategies. From this process, the student will be able to interpret results based on each patient’s condition, utilizing clinical reasoning and critical judgment.
Eighth semester	Musculoskeletal rehabilitation	To perform effective treatments for musculoskeletal dysfunctions, using clinical reasoning to select the most appropriate therapeutic tools, and accurately executing all procedures for each health condition.
	Cardiorespiratory rehabilitation	To establish an intervention plan according to the needs of patients, utilizing clinical assessments, pathophysiological reasoning, and a comprehensive health model to contribute to solving the cardiorespiratory problems of the population.
	Neurorehabilitation	To develop, execute and support a basic neurorehabilitation intervention plan that includes the application of physical therapy strategies and maneuvers. This plan involves selecting appropriate therapeutic tools according to the individual and environmental characteristics of the adult patient with a neurological condition.

### Appendix B. LAD prototype sections

LAD section	Related question	Indicators	Figure	Supported SRL strategy <sup>1</sup>
First section	<i>Which is my level of achievement of procedural skills to date?</i>	—Pie chart that shows the student’s percentage overall performance in the selected course. —Bar chart showing the average performance of students at each stage and at the global level in the selected course, highlighting the percentile in which the student is, allowing them to compare their performance.	Figure 2A	Self-evaluation and Goal setting
	<i>Where do I rank in terms of overall performance compared to the course?</i>			
Second section	<i>What are my best and worst performance items?</i>	—Radar graph that shows the student the average score the students obtained on each item, allowing them to observe the differences in performance between items.	Figure 2B	Self-evaluation and Goal setting
	<i>How am I doing compared to the course?</i>			
Third section	<i>How is my learning curve?</i>	—Line graph that shows the student’s performance at each stage completed, allowing to clearly see variations from one stage to another.	Figure 2C	Self-evaluation and Goal setting
Fourth section	<i>Which stages have I completed and how many stages are left?</i>	—Timeline where each milestone is a stage of the course represented by a box, containing the name of the stage and the performance (%) of the student in that stage. In addition, by clicking on a box, a window with the description of the stage is displayed to know the specific contents of it.	Figure 3D	Strategic planning and Task strategy
	<i>How do I incorporate this information to plan better?</i>			

LAD section	Related question	Indicators	Figure	Supported SRL strategy <sup>1</sup>
Fifth section	<i>What do I need to improve?</i>	—Indicator that shows the feedback delivered by the instructor in text form, at a given stage. Each comment also has the specific minute of the video response to which the comment corresponds.	Figure 3E	Strategic planning and Elaboration
Sixth section	What should I modify to improve in the next stage?	—Video tutorial of the current stage (which has not yet expired) to remind the student to watch it. —Mailbox to upload their video-response without having to leave the page.	Figure 3F	Elaboration and Task Strategy
Seventh section	<i>What meaning am I giving to feedback?</i>	—Mailbox to write and submit a self-reflection on their performance or on the feedback received in the recently completed stage.	Figure 3G	Self-evaluation and Elaboration
Collaborative forum	How can I enhance my learning process through the contribution of my peers?  How can I contribute to my peers' learning process?	—Forum to promote student SRL help-seeking strategy by allowing them to ask and answer questions of their peers.	Figure 4	Help seeking

<sup>1</sup> The SRL-supported strategies were established according to definitions provided by Kizilcec et al. (2017, p. 21).

## Appendix C. Protocol for Cognitive Walkthroughs

1. Welcome and brief introduction: Researchers introduce themselves, describe the context of the project, and explain the objectives of the interview.
2. Participant background questions:
  - Could you introduce yourself briefly by indicating your name and year of entry?
  - Have you used the feedback-oriented platform? In which context? With what learning objective?
3. LAD navigation: The student must perform the following tasks:
  - a) Log into a feedback-oriented platform and then into the dashboard.
  - b) Select a course to see the learning information.
  - c) Make a general free navigation indicating your appreciation with respect to each section.
  - d) Analyze the percentage of skill attainment and rank compared to the course in terms of percentiles (Figure 2A).
  - e) See which items of the assessment instrument have the highest and lowest scores per stage and compare to the course (Figure 2B).
  - f) Check the curve of your performance across the stages (Figure 2C).
  - g) See the instructions regarding course stages and deadlines (Figure 3D).
  - h) Check the text feedback inputs provided for each stage (Figure 3E).
  - i) Check the video tutorial of the next stage (Figure 3F).
  - j) See the self-evaluation box section (Figure 3G).
  - k) See the collaborative forum prototype (Figure 4).

In each task, researchers take notes while the students are asked to verbalize their understanding of the task performed, sharing their perception of its usability and usefulness.

4. Usability questions: The group of students must answer the following questions at the end of the cognitive walkthrough session.
  - What use would you make of this LAD after learning about it?
  - What indicators or information is most relevant to you?
  - What indicators or information do you think is missing from this LAD?
  - What indicators or information do you think is unnecessary?
5. Acknowledgments and closing: Students are thanked for their participation, and researchers share some remarks to finish the session.