Exploring learners' self-reflection and intended actions after consulting learning analytics dashboards in an authentic learning setting

Tornike Giorgashvili[1 [0009−0004−9465−3949]], Ioana Jivet[1,2,6], Cordula Artelt[3], Daniel Biedermann[2], Daniel Bengs[2], Frank Goldhammer[2,5], Carolin Hahnel[2,4], Julia Mendzheritskaya[1], Julia Mordel[1], Monica Onofrei[3], Marc Winter[1], Ilka Wolter[3], Holger Horz[1], and Hendrik Drachsler[1,2 [0000−0001−8407−5314]]

[1] Goethe University, Frankfurt am Main, Germany
[giorgash@sd.uni-frankfurt.de]
*studium**digitale** & Faculty of Computer Science, Educational Psychology*
[2] DIPF | Leibniz Institute for Research and Information in Education, Germany
[3] LIfBi | Leibniz Institute for Educational Trajectories, Bamberg, Germany
[4] Ruhr University Bochum, Germany
[5] Centre for International Student Assessment (ZIB)
[6] CATALPA, FernUniversität in Hagen, Germany

Abstract. Learning Analytics Dashboards (LAD) have been developed as feedback tools to help students self-regulate their learning (SRL), using the large amounts of data generated by online learning platforms. Despite extensive research on LAD design, there remains a gap in understanding how learners make sense of information visualised on LADs and how they self-reflect using these tools. We address this gap through an experimental study where a LAD delivered personalised SRL feedback based on interactions and progress to a treatment group, and minimal feedback based on the average scores of the class to a control group. Following the feedback, students were asked to state in writing how they would change their study behaviour. Using a coding scheme covering learning strategies, metacognitive strategies and learning materials, three human coders coded 1,251 self-reflection texts submitted by 417 students at three time points. Our results show that learners who received personalised feedback intend to focus on different aspects of their learning in comparison to the learners who received minimal feedback and that the content of the dashboard influences how students formulate their self-reflection texts. Based on our findings, we outline areas where support is needed to improve learners' sense-making of feedback on LADs and self-reflection in the long term.

Keywords: Learning Analytics Dashboards · Self-Regulated Learning · Self-Reflection · Psychometrics · Formative Feedback · Learning Design.

1 Introduction

Learning Analytics (LA) is an interdisciplinary field of research that deals with the collection, analysis and application of data about learners and their contexts

in order to optimise learning and learning environments in which it occurs. The data generated from a variety of digital learning platforms captures user interactions, learning progress, access times, and other specific learners' activities to build a comprehensive picture of their learning behaviour [25].

LA results are made available in various ways, with personalised email messages and Learning Analytics Dashboards (LADs) being among the most common methods [17]. Personalised emails can provide learners with specific feedback on their progress, advice on learning resources or recommendations for adjusting their learning strategies [18]. LAD is a visual representation of learning progress and patterns that both learners and teachers can use to gain insight into the learning process and make targeted interventions [28]. LADs for students are becoming increasingly popular, as evidenced by the growing number of LADs that have been developed and the increasing number of systematic reviews [12, 19, 15] in the recent years. However, despite the growing interest and research that has emerged concerning LADs, there remains a significant research gap in the understanding of learners' self-reflection and adaptation intentions after receiving personalised feedback. In addition, we have limited knowledge on how and to what extent the content of the feedback has an influence on the aspects on which learners intend to focus their attention.

The present study aims to contribute to the growing body of research on LADs by investigating, through a controlled study in an authentic learning setting, how students interpret personalised feedback provided through LAD. Our results will contribute to a better understanding of the effects of dashboards in terms of actions students intend to take after consulting a dashboard and to the further development of LADs designed to optimise LAD adoption.

2 Background

Personalised feedback is widely recognised as a valuable tool for increasing student engagement and promoting targeted improvements in learning outcomes [9]. Wang et al. [29] have shown that feedback, including prediction results and learning suggestions, increases learners' awareness, motivates them to adjust their learning progress and improves their performance in online contexts. Bulut et al. [4] highlighted the effectiveness of personalised feedback in different educational settings, especially through digital score reports, to improve motivation and performance. In their feedback models, Hattie and Timperley [9] and Nicol and Macfarlane-Dick [20] emphasise the need for specific, timely and actionable feedback that is tailored to the individual needs of learners in order to promote self-regulated learning (SRL) and enable deeper engagement with the subject matter.

In order to be effective, however, feedback needs to be taken up by students, for which engaging with and reflecting on the received feedback are essential [5]. Forsythe & Johnson [8] emphasised the importance of student perception in the use of feedback. Reflective writing coupled with feedback enhances students' reflective skills, motivates them to think more deeply about the content and

improves feedback processing [3]. Actively involving students in the feedback process and allocating time for reflection tasks is essential for critical engagement with both the feedback and the taught content [23, 30].

Since the early 2010s, LADs have emerged as key technologies for personalised learning support and feedback delivery [27]. They are expected not only to provide insights into learning progress to both teachers and students, but also to support metacognition and SRL through visualised data and personalised feedback that encourages learner reflection and decision-making [19, 28]. There are numerous works on how to design dashboards [2, 12, 14]. For example, any dashboard design should be based on learning science principles to increase engagement and motivation [24]. Furthermore, involving students in the process of developing LADs and considering their perspectives on the use and value of these tools is essential for optimising their learning impact [1].

With many design recommendations available, dashboards' effectiveness to improve performance, motivation and student attitudes has already been challenged [15]. However, the intermediary step of understanding how students make sense of information shown on dashboards and what actions they take as a result has been less explored. Kitto et al. [16] suggested that the development of LA for students should emphasise the promotion of key skills such as sense-making, metacognition and reflection, which can influence how students interpret and respond to feedback [16]. Corrin and de Barba [7] had already explored how student interpreted the feedback delivered through LADs. They found that even though most students could identify gaps in their performance, the format of the visualisation could prove confusing and students were unable to link their feedback to their current strategies. Lim et al. [18] investigated how four different reference frames can impact student's interpretation of the dashboard and how they intend to act on the feedback provided. Across all conditions, students' reflection and consequent actions revolved around time and study environment management. Their results emphasised the need to personalise LADs to learners' needs and include support to aid student sensemaking. Smith [26] also recommended supporting students to interpret dashboards effectively, noting that guidance and support in understanding feedback can increase its impact. In another study, Iraj et al. [10] showed that personalised feedback messages, especially with action-oriented prompts, motivate students to participate in the learning process actively and engage even more with the course materials.

Building on this previous work, in this study, we further explore how students reflect when using a LAD and what actions they intend to take as a result of receiving personalised feedback through such devices. We rest our research on the premise that students' interpretation of feedback delivered through LADs is crucial to the effectiveness of LADs in the learning process.

2.1 This Study and RQs

The current study was conducted as part of a larger project that aimed to investigate the impact of personalised feedback on learners' behaviour in a digital learning environment. Students received feedback on four key aspects of SRL:

elaboration, regulation, control and planning via a LAD embedded in the Moodle LMS. The chosen processes reflect activities that take place throughout the SRL stages according to Zimmermann [32], but address key aspects relevant to the cognitive (elaboration) and metacognitive regulation (planning, regulation and control) of the learning tasks as captured by the Motivated Strategies for Learning questionnaire (MSLQ) [22] and Learning and Study Strategies Inventory (LASSI) [31]. Additional criteria for the selection were processes that are sensitive to change through feedback and for which indicators can be derived on the basis of processing behavior within the LAD. Finally, we collaborated with the course lecturers to ensure that the processes matched the learning objectives and the structure of the course.

Feedback mechanisms based on the Hattie and Timperley's model [9] were built into the dashboard, providing feed-back with an interpretation of the learning behaviour and feed-forward with tailored suggestions for improvement. To test the impact of feedback, participants were randomised into a treatment group (TG) that received detailed, personalised feedback on SRL based on their specific interactions and learning progress as described in section 3. In contrast, all students in the control group (CG) received the same generic feedback text limited to the average scores for the four rated SRL aspects from the current cohort, with no individualised adjustments or recommendations. After receiving formative feedback via the LAD, participants in both groups were prompted to write a self-reflection (see Section 3) with the following questions: "*What aspects would you like to take into account more in your future work with the course materials? What changes would you like to make in your learning behaviour?*".

The detailed analysis of students' self-reflection sheds light on what insights the feedback offered them and, as a consequence, what actions they intend to take with regard to their learning. This research aims to fill the gap in understanding how students interpret and use the feedback they receive on LA dashboards. Through in-depth analysis of the reflections, we aim to paint a comprehensive picture of how learners integrate information from feedback delivered through LADs into their self-regulation practices. This exploratory study is guided by the following research questions:

RQ1: What aspects do learners intend to focus on as mentioned in their reflection texts after receiving formative feedback via the LA dashboard?

RQ2: Are there differences in the aspects mentioned in the reflection texts of learners who receive personalised feedback and those who do not?

RQ3: To what extent does the feedback content influence the aspects learners intend to focus on as written in their reflection texts?

3 The Learning Analytics Dashboard

The dashboard combines descriptions, personalised statistics, extensive feedback and prompts for self-reflection (see Fig. 1). Rule-based algorithms and data-driven analytics were used to populate the dashboard with content similar to the OnTask system [21]. The indicators that operationalize the four SRL aspects

that were feedbacked were computed using students' interaction data: switching between pages with learning materials in the LMS (elaboration), access to the pages describing the assignments and time difference between first access to the assignment and the deadline (planning), frequency of going back to learning materials while answering a learning unit quiz, use of the digital notepad during answering the quiz and checking answers before submitting the quiz (control) and returning to learning materials or looking at the notes after looking at the self-test solution (regulation).

Section A: Detailed SRL dimensional description. This section provides TG learners with a detailed description of four main dimensions of SRL that were feedbacked: Elaboration, Regulation, Control and Planning (see Fig. 1, A). In contrast, the CG only receives a general description of these dimensions.

Section B: Personalised SRL Statistics visualises the learner's performance in relation to the four SRL dimensions using bar graphs across all learning units of the course. The y-axis represents the percentage attained and was calculated based on threshold values of behaviour indicators that operationalise each of the four dimensions. For the TG, the individual performance scores are shown here, while the CG receives average scores from the current cohort. Dimension values from all five topics of the course are shown to allow students to monitor their progress over the semester.

Section C: Detailed and Personalised Feedback differs between TG and CG. The TG feedback includes detailed information on (1) the current status in the four dimensions of SRL (feed-back), (2) insights into observed learning behaviour (feed-back), and (3) tailored recommendations for improvement in each of the four dimensions (feed-forward) (see Fig.1, C). For example, feedback on current learning status might read: "*You have linked your previous knowledge to the new content in an appropriate way, but you have shown little planning behaviour.*". Students also received suggestions in the form of hints were formulated as follows: "*Try going back to the learning resources as you complete the self-test.*", or "*From now on, try to switch between resources more frequently to make links and connections.*" (see Table 3). The hints shown to each learner were selected based on threshold values of indicators that operationalize each of the four dimensions, i.e., lower values of indicators trigger certain hints.

Below the feedback, learners were prompted to self-reflect on how they intend to adapt their learning behaviour based on the feedback received. Students could record their self-reflection as free text. This requirement for written learner self-reflection is seamlessly integrated as a learning activity within the course in the LMS, enabling learners not only to critically examine how they approach learning in the course, but also to develop concrete plans for optimising their learning. Learners' reflection texts form the basis of the research conducted in this study. They serve as key data (1) to gain insight into learners' interpretation of feedback, (2) to gain insights into actions learners intend to take after receiving feedback through the dashboard, (3) to assess the impact of feedback on their intentions, and (4) to record changes in students' intentions regarding their learning behaviour over time.

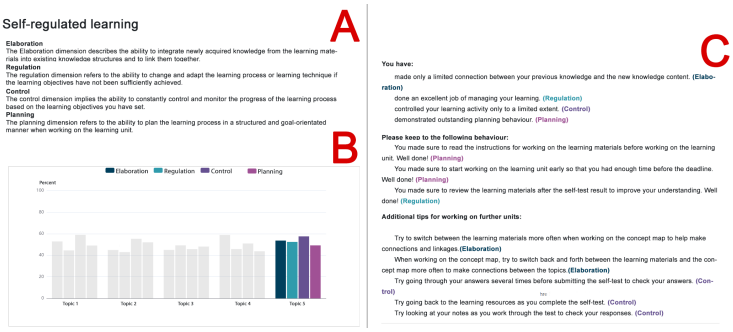

Fig. 1. The learning analytics feedback dashboard for the treatment group.

Technical implementation. The dashboard data was collected via a Moodle plugin from the Edutex software infrastructure [6] that logged learner interactions with course materials, click and scroll behaviour, access times, dwell times, discussion forum participation and assignment submission and stored it in a MongoDB database. The dashboard, developed as a Moodle plugin with HTML5, CSS3, JavaScript (frontend) and PHP (backend), stored evaluation data of the students' feedback and self-reflection texts in a MySQL database. A REST API seamlessly integrated the dashboard into Moodle, with particular attention paid to data security and GDPR compliance.

4 Methodology

Context and study participants: The system described in section 3 was deployed in an online course offered on Moodle on the use of digital media in teaching for first semester teacher students at two German universities. The learning content was structured in five learning units and delivered through a combination of video lectures, reading assignments and interactive exercises. In addition, discussion forums and peer feedback tasks encouraged learners to actively participate and exchange ideas with their peers. A total of 742 learners enrolled with the intention to participate in the course. On average, students were 22 years old (std = 5) and were predominantly women (70.5% women, 21.4% men, 0.3% diverse). All participants were informed about the purpose of the study, the use of their data and their rights before the study began. Participation in the study was voluntary and students had to agree to a consent form integrated into the Moodle system. Approval by an ethical review committee confirmed the ethical soundness of the study design and data collection procedures.

Data collection and preparation: Data collection took place from 31 October 2020 to 18 January 2021, during which we collected a total of 1,311 reflection texts from 529 students across three learning units. The final sample size analysed in this paper includes data from 417 students, 223 in the TG and 194 in the CG. This was made up of students who visited the LAD and wrote reflection texts every learning unit, resulting in a total of 1,251 reflection texts.

Table 1. The final coding scheme with aspects mentioned in student reflection texts.

Name	Code Description
Learning strategies (LS)	
Control	Checking the correctness of quiz answers with the learning material.
Take notes	Making notes, bullet points, summarising learning content.
Content engagement	Engaging with the learning materials that deliver the content of the course (e.g., watching videos, reading texts).
Elaboration	Linking new information to existing knowledge to deepen understanding.
Switching	Switch between different learning materials, e.g. from text to video.
Reflection	Thinking about and internalising the content of the course.
Other strategies	References to highlighting, researching literature, self-testing, engaging with peers, revisiting wrong answers in the quiz, repetition and others.
Course materials (CM)	
Learning materials	References to learning materials with content (e.g., videos, texts).
Quizzes	References to tests or self-tests, like quizzes and test tasks.
Feedback	References to the received feedback on the dashboard.
Assignments	References to specific learning tasks, such as homework assignments.
Concept Map	References to concept maps for structuring and visualising knowledge.
Instructions	Reading or working through instructions for completing assignments.
Self-regulated learning (SRL)	
Planning	Planning time to study learning materials.
Self Reflection	Reflecting on performance, course progress and used learning strategies.
Regulation	Deliberate adjustments to their learning strategies and behaviours based on the evaluation of their learning experiences.
Goal setting	References to learning goals or preparations for learning.
Monitoring	References to self-observation of the progress, performance or the learning process.
Other SRL Strategies	References to structuring of learning sessions and other metacognitive aspects related to learning.
Learning environment (LE)	
Concentration	References to being focused during learning.
Distraction	Identifying potential learner distractions with the aim of minimising them.
Environment	Creating a calm and productive environment for learning.
Emotional level (EL)	
Emotions	Learners recognise and refer to their emotional states.
Motivation	Mentions of motivation and strategies to stay motivated while learning.
Stress	Mentions of stress or strategies to manage and reduce stress.

Analyses: To gain an insight into the aspects students intended to focus on after consulting the dashboard, we started with a qualitative analysis of the self-reflection texts. The first step was to develop an emergent codebook that is available on OSF: https://osf.io/tvays/.

Three coders worked together in an iterative process to code the reflection texts. The development of the codebook began with a random selection of one-third of the reflection texts, which were analysed independently by each coder. The individual codebooks created by each coder were discussed, merged and refined in several joint working sessions. This collaborative process resulted in a final codebook that formed the basis for the systematic coding of all reflection texts. To ensure consistency and reliability of coding, the texts were coded in several iterations, with coding reviewed and adjusted after each round. In addition, all coding performed was double-checked to ensure accuracy. An inter-coder reliability test (Krippendorff's alpha = 0.722) confirmed an acceptable level of agreement between the coders. The final codebook consisted of five main categories that grouped references to specific learning activities and materials of the course, learning strategies, self-regulated learning strategies, the physical or digital learning environment and references to the emotional and motivational

aspects of learning (see Table 1). For each code, the self-reflection texts were coded with a binary variable: 1 if the aspect was mentioned by the student at least once and 0 if not.

To answer RQ1, we present the results of the qualitative analysis with descriptive statistics of the codes present in the reflection texts. To compare the distribution of thematic content in the self-reflection texts between the treatment and control groups (RQ2), we report the results of Chi-square (χ^2) tests. To analyse the influence of the feedback content on the intentions that students expressed in their reflection texts (R3), we built binomial logistic regressions, one for each code in our coding scheme. The codes defined in the codebook served as dependent binary variables, while the hints students received on the dashboard (see Table 3) also in a binary form (1 for hint received, 0 for hint not received) and the belonging to the treatment of the control group served as predictors. We conducted all analyses with jamovi (https://www.jamovi.org/).

5 Results

5.1 Aspects mentioned in student reflection texts (RQ1)

The results of our qualitative analysis summarised in Table 2 show that students paid particular attention to *Learning Strategies* (LS), with a total of 969 (77.5%) self-reflection texts across the three learning units that mentioned or described at least one learning strategy. One third of all self-reflection texts included a reference to checking the quiz answers against learning materials before submission (406 mentions, 32.5%). Taking notes (325 mentions, 26%) and engaging with the course content (288 mentions, 23%) were commonly mentioned strategies that underline an intention towards an organised and structured approach to the learning process, while a focus on elaboration (258 mentions, 20.6%) reflects intentions to engage more deeply with the learning material.

Students made references to specific learning materials or activities in 68.4% of the self-reflection texts (856 mentions). For instance, learning materials that delivered content (e.g., videos or texts) were mentioned in one third of the self-reflection texts indicating that consuming learning content was a priority for students. *Quizzes* (445 mentions) were also mentioned in a third of the self-reflections, highlighting an intention to optimise self-testing. Students rarely referenced the feedback received (119 mentions, 9.5%).

References to self-regulated learning strategies (682 mentions) were made in more than half of the self-reflection texts (54.5%) with planning (448 mentions, 35.8%) being the aspect students intended to focus on the most. In 19.1% of the recorded texts, students showed that they were actively evaluating their past performance and self-reflecting on their progress (239 mentions) with a further 140 (11.2%) texts showing that students intended to focus on adapting their learning approaches (i.e., regulating).

Less mentioned were references to creating a conducive physical and digital learning environment. Nonetheless, in 10 % of the reflection texts, students

addressed the challenges of attention control and mentioned they intended to increase their concentration (85 mentions, 6.8%) or minimise distractions (39 mentions, 3.1%). Finally, our coding scheme captured students' mentions of emotional and motivational aspects of learning in a very low number of self-reflections (47 mentions, 3.8%).

Table 2. Aspects mentioned in 1251 student reflection texts collected from 417 students in three learning units.

	Total	CG (N=194)		TG (N=223)		χ^2		
	# ment.	# ment.	% ment.	# ment.	% ment.	value	p	
Learning Strategies	*969*	*435*	*74.7%*	*534*	*79.8%*	*4.6*	*0.032*	*
Control	406	95	16.3%	311	46.5%	129.0	<.001	***
Take notes	325	136	23.4%	189	28.3%	3.9	0.049	*
Content engagment	288	194	33.3%	94	14.1%	65.3	<.001	***
Elaboration	258	97	16.7%	161	24.1%	10.4	0.001	**
Switching	122	8	1.37%	114	17%	86.8	<.001	***
Reflection	116	54	9.28%	62	9.27	<.001	0.995	
Other strategies	*539*	*230*	*4.39%*	*309*	*5.12%*			
Course Materials	*856*	*328*	*56.4%*	*528*	*78.9%*	*73.4*	*<.001*	***
Learning materials	448	190	32.6%	258	38.6%	4.744	0.029	*
Quizzes	445	101	17.4%	344	51.4%	157.6	<.001	***
Feedback	119	23	4.0%	96	14.3%	39.1	<.001	***
Assignment	59	31	5.3%	28	4.2%	0.9	0.342	
Concept Map	56	18	3.1%	38	5.7%	4.9	0.027	*
Instructions	44	5	0.86%	39	5.83%	22.66	<.001	***
SRL	*682*	*391*	*67.2%*	*291*	*43.5%*	*70.4*	*<.001*	***
Planning	448	275	47.3%	173	28.9%	62.0	<.001	***
Self Reflection	239	139	23.9%	100	14.9%	16.1	<.001	***
Regulation	140	75	12.9%	60	9.7%	3.2	0.076	
Goal setting	41	30	5.15%	11	1.64%	12.1	<.001	
Monitoring	28	18	3.09%	10	1.9%	3.63	0.057	
Other SRL	*160*	*106*	*18.2%*	*54*	*5.1%*			
Learning environmt	*125*	*112*	*19.2%*	*13*	*1.9%*	*103.6*	*<.001*	***
Concentration	85	77	13.2%	8	1.1%	71.2	<.001	***
Distraction	39	38	6.5%	1	0.1%	41.9	<.001	***
Environment	34	30	5.2%	4	0.6%	24.4	0.342	
Emotional level	*47*	*22*	*3.8%*	*25*	*3.7%*	*0.001*	*0.968*	***
Emotions	24	14	2.4%	10	1.5%	1.4	0.241	***
Motivation	15	5	0.9%	10	1.5%	1.1	0.303	***
Stress	11	4	0.7%	7	1.0%	0.5	0.497	

*Note: *** p<.001; ** p<.01; * p<.05.*

5.2 Differences in self-reflection between groups (RQ2)

We identified significant differences in terms of content between the treatment and the control group, as shown by the results of the Chi-square tests in Table 2. Students who received personalised feedback (TG) mentioned or described learning strategies more often than students who received generic feedback (CG) ($\chi^2 = 4.6, p.032$). Specifically, students that received personalised feedback expressed the intention to check their answers before submitting quizzes or as-

signments three times more often than students who received generic feedback ($\chi^2 = 129, p < .001$). Students in the treatment group also expressed intentions to engage on a deeper level with the content of the course through elaboration ($\chi^2 = 10.4, p < .001$) and intentions to switching more between different types of learning materials ($\chi^2 = 86.8, p < .001$) significantly more than they peers in the control group. On the other hand, students in the control group expressed twice as often intentions to simply consume learning content ($\chi^2 = 65.3, p < .001$) although be it in a faster, more focused or intensive way.

Course materials were significantly more often referenced by students in the treatment group ($\chi^2 = 73.4, p < .001$), suggesting an intention to engage deeper with specific learning activities and possibly a more critical reflection on the materials used. Thus, students who received personalised feedback mentioned learning materials, quizzes, the concept map and the assignment instructions significantly more than students who received generic feedback. Additionally, they also referred to the received feedback almost four times as much as students with generic feedback ($\chi^2 = 39.1, p < .001$).

In terms of self-regulated learning, we found the opposite. Students in the control group expressed intentions to adapt their SRL strategies significantly more often ($\chi^2 = 70.4, p < .001$). This finding applied to almost all coded aspects of SRL: planning, self-reflection and goal setting. In other words, students who received the generic feedback were more likely to intend to work on aspects of their self-regulation compared to students who received personalised feedback.

The learning environment showed the greatest difference in mentions ($\chi^2 = 103.6, p < .001$), with the TG making the learning environment a topic of reflection significantly less often than the CG, indicating a different perception or prioritisation of physical and digital learning conditions. We found no significant difference between the two groups regarding references to motivational and emotional aspects of learning.

5.3 Feedback content influence on self-reflection texts (RQ3)

To understand whether the personalised content shown on the feedback dashboard can be responsible for the differences identified in the previous section, we first look at the hints students received on the LAD (see Table 3).

The results of binomial logistic regression with hints received by students and the belonging to a treatment or control group as the nine predictors and the self-reflection codes as outcome variables are shown in Table 4. The regressions show whether the presence of student intentions in the self-reflection texts can be explained by the hints students received on the dashboard. Due to lack of space, we present only the regressions that showed a significant model fit and the predictors that showed significant relationships.

Our analyses show that the mention of four learning strategies in the self-reflection texts can be predicted by the hints students received on the dashboard. Specifically, students who were shown a recommendation to review their answers before submitting the test (T6) were more than twice as likely to include this strategy in their self-reflection (B = 0.93, Z = 3.04, p = .002, OR = 2.53) that

Table 3. Overview of the hints integrated in the dashboard and shown to learners in the treatment group (223 out of 471) over three learning units.

	Prompt	LU1	LU2	LU3
T1	Try looking at your notes as you work through the test to check your responses.	220	183	193
T2	Try going back to the learning resources as you complete the self-test.	203	136	106
T3	Try to follow the instructions as you work through the resources.	200	133	128
T4	From now on, try to switch between resources more frequently to make links and connections.	199	171	81
T5	Try reviewing the learning materials after taking the self-test to improve your understanding.	190	208	211
T6	Try to review your answers several times before you submit the test.	190	208	211
T7	Try to start working on the learning unit much earlier. This will give you enough time before the deadline.	4	20	13
T8	When working on the concept map, try to switch between the learning materials and the concept map more often to make connections between the topics.	0	0	156

Note: T8 was only given in learning unit 3.

students who did not receive this prompt. Similarly, students that were suggested to check their notes as they are working the quizzes (T1) were more than three times more likely to intend to take notes (B = 1.19, Z = 3.25, p = .001, OR = 3.29). Finally, when given the hint to switch between learning materials in order to build link between new knowledge and already learned content (T4), students are five times more likely to intent to work on this aspect (B = 1.71, Z = 5.63, p = <.001, OR = 5.55) and more than twice as likely to intend to switch between materials more often (B = 0.99, Z = 3.09, p = .002, OR = 2.68).

In terms of learning materials, students that were prompted to check the answers before submission (T6) were twice as likely to mention quizzes in their self-reflections (B = 0.82, Z = 2.76, p = .001, OR = 2.27). Furthermore, students that received T8, being suggested a way to work with the concept map were four times more likely to make references to the concept map (B = 1.57, Z = 3.81, p = <.001, OR = 4.83). A similar pattern is observed also when looking at the mention of assignment instructions, when being suggested to consult the instructions provided by the teachers of the course (T3), students are almost seven times more likely to consider in their further actions (B = 1.94, Z = 3.96, p = <.001, OR = 6.98). Finally, when prompted to consult the instructions from the instructors (T3), students are 2.46 times more likely to want to focus on better planning of their learning (B = 0.14, Z = 0.64, p = .002, OR = 2.46).

6 Discussion

The present study aimed to gain a deeper understanding of learners' reflection and actions they intend to take after consulting feedback received on a LAD. Analysing the reflection texts of 417 learners revealed that mentions or descriptions of learning strategies, course materials, self-regulated learning strategies, the learning environment and emotional aspects are present in students' self-reflection texts (*RQ1*). The analysis shows that 77.5% of the self-reflection texts deal with learning strategies, with a focus on checking quiz answers (32.5%) and taking notes (26%). Specific learning activities are mentioned in 68.4% of the

Table 4. Binomial regression results showing how feedback content influence student intentions expressed in their self-reflection texts.

						Model Fit Measures		
Dependent	Predictor	B	Z	p	OR	R^2 McF	χ^2	p
Control						*0.109*	*173*	*<.001*
	T3	-0.48	-2.54	0.01	0.62			
	T6	0.93	3.04	0.002	2.53			
	T7	-0.80	-2.13	0.03	0.45			
Take notes						*0.023*	*33.4*	*<.001*
	T1	1.19	3.25	0.001	3.29			
	T3	-0.66	-3.24	0.001	0.52			
Elaboration						*0.044*	*55.6*	*<.001*
	T4	1.71	5.63	<.001	5.55			
Switching						*0.155*	*124*	*<.001*
	T4	0.99	3.09	0.002	2.68			
Quizzes						*0.131*	*214*	*<.001*
	T3	-0.76	-3.94	<.001	0.47			
	T5	-0.57	-2.34	0.02	0.56			
	T6	0.82	2.76	0.01	2.27			
	T7	-0.87	-2.35	0.02	0.42			
	T8	-0.55	-2.61	0.01	0.57			
Concept Map						*0.2*	*91.3*	*<.001*
	T2	-1.07	-2.04	0.04	0.34			
	T4	-1.44	-2.47	0.01	0.24			
	T8	1.57	3.81	<.001	4.83			
Clues						*0.169*	*64.2*	*<.001*
	T1	-1.33	-2.21	0.03	0.27			
	T3	1.94	3.96	<.001	6.98			
	T8	-1.59	-2.43	0.02	0.20			
Planning						*0.056*	*54.1*	*<.001*
	T3	0.14	0.64	0.02	2.46			

texts, with a third referencing quizzes. As the quizzes were formative in nature and did not contribute to students' grade in the course, these results highlight students' preference for self-testing their knowledge that can act as a proxy for gauging their understanding of the subject matter. Strategies for self-regulated learning are present in 54.5% of the reflections, with a focus on planning (35.8%), suggesting that strategically allocating time for learning or simply starting earlier was an action that students considered worth addressing to improve their learning. This is an encouraging finding as previous studies have shown that supporting time management is a challenge that LADs can address [18].

Regarding *RQ2*,we found that students who received personalised feedback expressed intentions to work on specific learning strategies a lot more often than their peers in the control group. This disparity might indicate the effectiveness of personalised LAD in promoting more conscious engagement with learning strategies. On the other hand, students who received generic feedback were more focused on improving their self-regulation strategies, in particular along the dimensions feedbacked on the dashboard. This result may indicate that when given concrete suggestions for improving their learning strategies, students are willing to implement it, but when such feedback is missing, their improvement strategies are more abstract are refer more often to general SRL strategies. Furthermore,

the less frequent mentions of the learning environment in the TG provides further evidence for this hypothesis. Personalised feedback increases learners' focus on content and more actionable aspects of learning, possibly eclipsing other important aspects of the learning process. Conversely, the lack of personalised feedback in the control group might lead learners to develop more creative approaches to designing and using an optimal learning environment.

We also explored the extent to which the content shown on the LAD directly influences the actions students intend to take or changes they intend to make with regards to their learning *(RQ3)*. The binomial logistic regressions showed that specific feedback tips on LADs have a significant impact on students' focus and adaptation of learning aspects: some tips reduce the likelihood of mentioning these aspects, others significantly increase it. This suggests the complexity of the interplay between the nature of the feedback and the individual learner's response to it. The numerous negative relationships between the presence of a hint on the dashboard and the intentions expressed in the self-reflection texts (see Table 4) could indicate that students do not take all the content that is shown on the dashboard into their self-reflections, but rather prioritise and select the aspects they consider most relevant. This underlines the relevance of including feedforward components into the feedback according to Hattie [9] and ensuring that LADs include support for action into their design [11].

We acknowledge several *limitations* of our study. Our analysis is limited to reflection texts collected after providing students with feedback on four SRL dimensions and neglects other relevant learning processes. In future research, we will extend these analyses to data collected in other courses where we provided students with a more comprehensive feedback content following [9]. Furthermore, the accuracy of the feedback algorithms and the operationalization of the feedback dimensions through trace data leaves room for speculation about the influence on learners' adaptation strategies, requiring a continuous review of the feedback criteria and the data used for generating feedback. Another limitation is that we measured students' intentions and not whether students actually applied the strategies mentioned in the self-reflections, a shortcoming we plan to address in future research. Finally, a very time-demanding task was the manual coding of the self-reflection texts. A possible solution to address this challenge is automated assessment of these texts using linguistic models [13].

7 Conclusion

This study provides insights into learners' self-reflection and action intentions after using LADs in an authentic learning context. It highlights the importance of LADs as tools to promote self-regulated learning by providing learners with personalised feedback paths and incentives to reflect on their learning processes. Future research should aim to shed light not only on which specific learning strategies students undertake in response to personalised feedback from LADs, but also on how carefully crafted feedback can nudge students towards effective strategies. Furthermore, future studies should also aim to explore the long-term

effects of LAD-based feedback on learning and to enable a more accurate assessment of the impact of LAD on learning processes through the use of data triangulation for more objective measurement methods. Our results emphasise the need to continually optimise LADs and adapt them to learners' individual needs in order to imrpove their learning success in a sustainable way.

References

1. L. Bennett and S. Folley. Four design principles for learner dashboards that support student agency and empowerment. *Journal of Applied Research in Higher Education*, 12(1):15–26, 2019.
2. R Bodily and K Verbert. Review of research on student-facing learning analytics dashboards and educational recommender systems. *IEEE Transactions on Learning Technologies*, 10(4):405–418, 2017.
3. M. V. Boekel, A. S. Hufnagle, S. Weisen, and A. Troy. The feedback i want versus the feedback i need: investigating students' perceptions of feedback. *Psychology in the Schools*, 60(9):3389–3402, 2023.
4. O. Bulut, M. Cutumisu, A. M. Aquilina, and D. Singh. Effects of digital score reporting and feedback on students' learning in higher education. *Frontiers in Education*, 4, 2019.
5. D Carless and D Boud. The development of student feedback literacy: enabling uptake of feedback. *Assessment & Evaluation in Higher Education*, 43(8):1315–1325, 2018.
6. G.P. Ciordas-Hertel, S Rödling, J Schneider, D Di Mitri, J Weidlich, and H Drachsler. Mobile sensing with smart wearables of the physical context of distance learning students to consider its effects on learning. *Sensors*, 21(19), 2021.
7. L Corrin and P De Barba. How do students interpret feedback delivered via dashboards? In *Proceedings of LAK15*, pages 430–431, 2015.
8. A. Forsythe and S. Johnson. Thanks, but no-thanks for the feedback. *Assessment & Evaluation in Higher Education*, 42(6):850–859, 2016.
9. J. Hattie and H. Timperley. The power of feedback. *Review of Educational Research*, 77(1):81–112, 2007.
10. H. Iraj, A. Fudge, H. Khan, M. Faulkner, A. Pardo, and V. Kovanović. Narrowing the feedback gap: Examining student engagement with personalized and actionable feedback messages. *Journal of Learning Analytics*, 8(3):101–116, 2021.
11. I Jivet, M Scheffel, M Schmitz, S Robbers, M Specht, and H Drachsler. From students with love. an empirical study on learner goals, self-regulated learning and sense-making of learning analytics in higher education. *The Internet and Higher Education*, 47:100758, 2020.
12. I Jivet, M Scheffel, M Specht, and H Drachsler. License to evaluate: Preparing learning analytics dashboards for educational practice. In *Proceedings of LAK'18*, pages 31–40, 2018.
13. Y Jung and A F Wise. How and how well do students reflect? multi-dimensional automated reflection assessment in health professions education. In *Proceedings of LAK'20*, pages 595–604, 2020.
14. R Kaliisa, I Jivet, and P Prinsloo. A checklist to guide the planning, designing, implementation, and evaluation of learning analytics dashboards. *International Journal of Educational Technology in Higher Education*, 20(1):28, 2023.

15. R Kaliisa, K Misiejuk, S López-Pernas, M Khalil, and M Saqr. Have learning analytics dashboards lived up to the hype? a systematic review of impact on students' achievement, motivation, participation and attitude. *Proc. of LAK24*, 2024.
16. K. Kitto, M. Lupton, K. Davis, and Z. Waters. Designing for student-facing learning analytics. *Australasian Journal of Educational Technology*, 33(5), 2017.
17. Lisa Lim, Shane Dawson, Srecko Joksimovic, and Dragan Gašević. Exploring students' sensemaking of learning analytics dashboards: Does frame of reference make a difference? In *Proceedings of the 9th International Conference on Learning Analytics & Knowledge (LAK19)*, pages 250–259, New York, NY, USA, 2019. Association for Computing Machinery.
18. Lim, L.-A., Dawson, S., Gašević, D., Joksimović, S., Fudge, A., Pardo, A., and Gentili, S. Your title here. *Your Journal Here*, Your Volume:Your Pages, 2020.
19. W. Matcha, Nora'Ayu Ahmad Uzir, D. Gašević, and A. Pardo. A systematic review of empirical studies on learning analytics dashboards: A self-regulated learning perspective. *IEEE TLT*, pages 1–1, 2019.
20. D J. Nicol and D Macfarlane-Dick. Formative assessment and self-regulated learning: a model and seven principles of good feedback practice. *Studies in Higher Education*, 31(2):199–218, 2006.
21. A Pardo, K Bartimote-Aufflick, S Buckingham Shum, S Dawson, J Gao, and D et al. Gasevic. Ontask: Delivering data-informed, personalized learning support actions. *Journal of Learning Analytics*, 5:235–249, 2018.
22. Paul R Pintrich, David AF Smith, Teresa Garcia, and Wilbert J McKeachie. Reliability and predictive validity of the motivated strategies for learning questionnaire (mslq). *Educational and psychological measurement*, 53(3):801–813, 1993.
23. S. Quinton and T. Smallbone. Feeding forward: using feedback to promote student reflection and learning – a teaching model. *Innovations in Education and Teaching International*, 47(1):125–135, 2010.
24. G. Sedrakyan, E. Mannens, and K. Verbert. Guiding the choice of learning dashboard visualizations: linking dashboard design and data visualization concepts. *Journal of Computer Languages*, 50:19–38, 2019.
25. G. Siemens. Learning analytics: The emergence of a discipline. *American Behavioral Scientist*, 57(10):1380–1400, 2013.
26. P. H. Smith. Engaging online students through peer-comparison progress dashboards. *Journal of Applied Research in Higher Education*, 12(1):38–56, 2019.
27. K. Verbert, E. Duval, J. Klerkx, S. Govaerts, and J. L. Santos. Learning analytics dashboard applications. *American Behavioral Scientist*, 57(10):1500–1509, 2013.
28. K Verbert, X Ochoa, R De Croon, R Dourado, and T De Laet. Learning analytics dashboards: the past, the present and the future. In *EuroVis Workshop on Visual Analytics*, pages 35–40, 2020.
29. D. Wang and H. Han. Applying learning analytics dashboards based on process-oriented feedback to improve students' learning effectiveness. *Journal of Computer Assisted Learning*, 37(2):487–499, 2020.
30. M. Weaver. Do students value feedback? student perceptions of tutors' written responses. *Assessment and Evaluation in Higher Education*, 31:379–394, 2006.
31. CE Weinstein, DR Palmer, and AC Schulte. Lassi online learning and study strategies inventory, 2006.
32. B J. Zimmerman. Attaining self-regulation: A social cognitive perspective. In M. Boekaerts and P. R. Pintrich, editors, *Handbook of self-regulation*, pages 13–39. Academic Press, New York, 2000.