The Third Wave of Self-Regulated Learning's Measurement and Intervention Tools: Designing 'Diaria' as a New Generation of Learning Diary

https://doi.org/10.3991/ijet.v18i09.35605

Baginda Anggun Nan Cenka, Harry B. Santoso, Kasiyah Junus(✉)
Universitas Indonesia, Depok City, West Java, Indonesia
kasiyah@cs.ui.ac.id

Abstract—Digital transformation accelerates the undertaking of online learning at various levels of education. Online learning mandates students to have high self-regulation skills. Therefore, self-regulated learning (SRL) plays an important role in the education field. The third wave of SRL measurements suggests how measurement is applied concurrently with the intervention. This study proposes a learning diary that we call Diaria to take part in the third wave. Diaria was developed using a user-centred design with three phases: design research, design prototype, and design evaluation. Usability testing was selected as an evaluation design method involving 30 participants. The evaluation results were examined based on several categories, including distribution of the System Usability Scale score, issues, task performance, and potential solution. An initial investigation of the impact of learning diaries on students' SRL skills was carried out as a pilot study. This experiment involved 24 participants in a linear algebra course. The interview method was applied to collect data, followed by a thematic content analysis to understand the resulting transcripts. The results showed that the prototype has good usability. In addition, recommendations for improvement are suggested. Further, the pilot study has shown that there are various student learning strategies and advantages to a learning diary and has provided valuable notes for the main study.

Keywords—self-regulated learning, learning diary, personal learning environment, user-centred design, usability testing

1 Introduction

In the current digital era, digital transformation in education is inevitable. Many educational institutions develop applications, provide infrastructure, and amplify human resources in the field of technology to realise digital transformation, which has been accelerated by COVID-19. As cited by Sahoo et al. [1], the World Economic Forum has predicted that the COVID-19 crisis will force various changes that will accelerate innovation in education, foster partnerships, and create a digital divide.

During the pandemic, online learning grew in popularity. Online learning diminishes traditional methods such as face-to-face learning and encourages spending more time on both online and asynchronous interactions. Barrot et al. [2] identified learning challenges

during the pandemic and divided them into seven categories: learning environment, self-regulation, learning resources, technological literacy and competency, technological complexity, technological sufficiency, and student isolation challenges.

Online learning requires students to have high self-regulation skills. Self-regulated learners are students who are metacognitively, behaviourally, and motivationally involved in their learning process [3]. Currently, self-regulated learning (SRL) plays a strategic role in the education field and is key in the development of digital literacy skills [4]. According to Haron et al. [5], SRL skills are an important predictor of academic performance. Scott [6] states that SRL and digital literacy are among the most prominent skills for education and professionals. According to Ejubovic and Puška [7], SRL is an essential factor in the success of online learning. In the context of computer science, SRL has a positive impact on academic performance in programming courses [8, 9].

There are three waves of SRL measurements, each of which complements the other. Panadero et al. [10] stated that the third wave, which combines measurement and intervention, needs to be given more attention. This study proposes and develops a learning diary as part of the third wave. Learning diaries are a platform that students can use to record what their goals are, what is important while studying, and how they feel after studying. Learning diaries are personal because they store and manage what students read, hear, feel, and think while they are studying, both inside and outside the classroom. Learning diaries are a form of personal learning environment (PLE). Based on the systematic literature review conducted by Cenka et al. [11], we define PLE as a socio-technical system that is fully orchestrated by students and integrates the collection of tools, services, and resources according to students' needs and preferences in formal, informal, and non-formal settings to promote educational and professional goals towards lifelong learning. Referring to this definition, we state that a learning diary is a form of PLE.

The learning diary was developed to fill the gaps in platforms that are currently used by students, such as the Learning Management System (LMS) and Massive Open Online Course (MOOC) platforms. At LMS and MOOC, the lecturer or instructor is in full control of orchestrating the student learning environment, whereas in the learning diary, students act as individuals and are given full control of managing their own learning environment according to their personal needs and preferences. Learning diaries can be used in formal, informal, and non-formal settings, which means that learning diaries help students to become lifelong learners. According to Mahajan et al. [50], the attributes of lifelong learning include metacognition skills, self-directed learning, reflective behaviour, and self-monitoring skills, and all these attributes are facilitated by a learning diary.

Based on the strengths of the learning diary and the weaknesses of current learning platforms, especially LMS and MOOC, there is an opportunity for the learning diary to become a promising platform for measuring, intervening, and training students' SRL skills. The objective of this study is to develop a prototype of Diaria, evaluate its design, and conduct a preliminary investigation into the impact of learning diaries on students' SRL skills. Therefore, we address the following three research questions (RQs) as our guidelines:

RQ1: What is the design of a learning diary that supports students' SRL skills?
RQ2: How are the prototype's design results evaluated?
RQ3: To what extent are the students' learning strategies utilised, and what are their perceptions of the learning diary?

This article is organised into eight sections. The first section explores the importance of SRL and the use of learning diaries as a tool to measure and intervene in SRL strategies. The second section summarises previous studies that elaborate further on SRL and learning diaries. The third section describes how the user-centred design (UCD) was used as a direction in prototyping and how the pilot study was accomplished. The fourth section describes the design research, which includes how designers identify the needs and features of learning diaries. The fifth section displays the results of the design in the form of information architecture, student journal maps, and mock-ups. The sixth section presents the results of the evaluation using the usability testing (UT) method. The seventh section describes the procedure and results of the pilot study. The discussion and conclusions of this study are presented in the last section.

2 Previous studies

This study aims to develop a learning diary that acts as a measurment and intervention tool for students' SRL skills. Therefore, a literature review of SRL research trends and learning diaries is necessary.

2.1 Self-regulated learning

Over the past two decades, SRL has been at the centre of research in the field of education [12], and this discourse has extended to other domains, such as computer science. SRL can be interpreted as a process that is organised by individuals. It begins with setting goals, performing to achieve these goals, and evaluating the execution to guarantee that the goals are accomplished [13]. SRL has been scrutinised by different authors. Silverajah et al. [14] state that there are the following six SRL models: (1) a cycle phase model by Zimmerman; (2) a six-component SRL model by Boekaerts; (3) the SRL model by Winne and Hadwin that included motivation in their models; (4) the SRL model by Pintrich with greater emphasis on metacognition; (5) a metacognitive and affective model of SRL by Efklides; and (6) a socially shared regulated learning model by Hadwin et al.

Most authors presented the following three stages of SRL: forethought, performance, and self-reflection. During the forethought phase, students set goals and create plans. This phase involves a task analysis and self-motivated beliefs. During the performance phase, students use various strategies to improve their learning. This phase applies self-control and self-observation. During the reflection phase, students reflect on their performance and evaluate the process and learning outcomes. This phase combines self-assessment and self-reaction [15].

Panadero et al. [10] identified three waves of SRL measurements. In the first wave, measurements were driven by relying on self-reports, such as questionnaires and interviews. The most common instruments include the learning and study strategies inventory, the motivated strategies for learning questionnaire, and the self-regulated learning interview schedule. In the second wave, measurements are delivered online, and the SRL is regarded as a collection of events. In this wave, think-aloud protocol, observation, and traces are the best options. In the third wave, Panadero et al. [10] declare

that there is a demand to integrate measurement and intervention concurrently. One example of its enactment is the use of learning diaries by Schmitz and Wiese [16] and Schmitz and Perels [17].

2.2 Learning diary

Learning diaries offer students possibilities for personal development and academic achievement and enable them to develop their metacognitive strategies [18]. They are valuable for reviewing students' abilities to reflect and encourage them to forge new ideas, log their practical activities, and record how they learn. Learning diaries improve students' SRL skills by enriching their awareness of what their current learning strategies are. In addition, learning diaries improve students' planning, self-monitoring, and self-reflection. Many researchers have found empirical evidence that learning diaries are advantageous in teaching and learning, and they report that learning diaries can improve metacognitive skills and attitudes, self-regulation, and self-efficacy [17, 19].

There are various formats for delivering a learning diary, such as the pen-and-paper method, online-based platforms, and mobile apps. Learning diaries can be operated as an SRL intervention tool for lecturers, where the interventions are usually administered in the classroom. Such traditional intervention methods are limited by space and time. For example, every teacher must measure and interact with every student in the class, which can be challenging because the students' personal goals might be different. Further, some students prioritise skills, whereas other focus only on grades. Moreover, they all have different learning strategies, and several students are more comfortable making summaries, whereas others prefer to create concept maps. In this setting, the intervention method for them is also different. In brief, it is impossible for this intervention to be carried out in a one-to-many fashion, which consumes a lot of time and resources. Nevertheless, these interventions are confined to the limitations of time and space. With the growth of technology, the interventions can be delivered online, usually using the web and mobile platforms [20].

3 Research methodology

The research methodology in the current study is outlined below.

3.1 Formulating the research problem

The initial phase of this study functions to formulate research problems, namely using gap analyses, where we find that there are limited SRL tools that can measure and intervene in SRL strategies, especially tools that are fully controlled by students. In the first wave of measurements, researchers considered SRL to be static, thus measurements using a questionnaire were the main choice at that time. In the second wave, SRL began to be considered as something dynamic, thus thinking aloud and observation were the most suitable choices as measurement methods. In these two waves, measurement and intervention are viewed as separate things, even though they are interrelated.

In the third wave, Panadero et al. stated that as SRL is a dynamic process, it is necessary to propose measurements and interventions at the same time. This is in accordance with Araka et al. [48], who state that a tool that can both measure and intervene in students in the SRL context is necessary. This idea was developed because the purpose of measuring is to discover the SRL skill level, which then suggests the appropriate interventions according to that level. This idea is popular with the emergence of the use of Educational Data Mining to identify, model, and predict student behaviour. In addition, Matcha et al. [49] state that the limitations of the available SRL tools are that they are often inconsistent with existing SRL theories.

Meanwhile, researchers argue that the learning diary combines self-reporting and logging, where it can record and explore a series of student activities over a certain period. In addition, the learning diary can be used to reflect on their activities. In this scenario, a learning diary is both a measurement and intervention tool [10]. Therefore, we have set out the objectives of this study to develop a prototype of a learning diary, evaluate its design, and investigate the impact of using a learning diary on SRL strategies and skills.

Fig. 1. Research methodology

In this study, UCD is used as a direction to lead prototyping. Garrett [21] depicts UCD as a method of designing an artifact that places the user at the centre of attention. UCD assists in the development phase to fulfil the users' requirements and capabilities, specifically for newcomers [22]. In the practice of UCD, Williams [23] states that designers have to create user profiles, identify behaviours and preferences, and drive decisions from that information. The UCD phases that are conducted in the current study are outlined below.

3.2 Design research

Bødker [24] articulated that the initial phase of UCD is investigating stakeholders and users. With the interview method, designers identify user goals, constraints, and assumptions to grasp the user's natural behaviour. This phase has two important activities, the first of which is choosing the target users of the learning diary and identifying their characteristics. This activity is very important as a starting point for design research. In this study, the target users are undergraduate students at a large and reputable public university in Indonesia. The second activity is conducting a literature study related to which features users need in a learning diary. Several features have been identified, including goal setting, resources, notes, mind maps, self-generated questions (SGQs), and reflections.

In this study, the user interviews were not directly administered in the first iteration of design because the prototype of the learning diary was operated as an SRL tool. Therefore, it is critical to initiate a literature study to define SRL. Once the designer has gained initial knowledge of SRL, the user studies are activated. Initially, the target users did not have sufficient knowledge of SRL because the users were computer science students who did not receive special training on SRL. The students only acquire SRL knowledge if they enrol in computer-assisted learning courses. Designers and users must have equal knowledge of SRL for the development process to be driven effectively and efficiently, and the designers must then identify user needs with a literature study and approve it for the target users.

3.3 Design prototype

Bødker [24] states that design is the second phase of UCD. In this phase, designers initiate a discussion, create concepts, and make initial sketches. This phase delivers information architecture (IA), which can be employed to investigate how information is managed; the student journey map (SJM), which is very helpful to understand how students interact in learning diaries; and the prototype, which can be used to visualise the working model of the application. There are two types of prototypes: low-fidelity prototypes, such as paper prototypes, and high-fidelity prototypes, which tend to be interactive. This study resulted in a high-fidelity prototype.

3.4 Design evaluation

Bødker [24] notes that design evaluation is the final stage in UCD. The evaluation strives to ensure that the artifacts that are produced fulfil the requirements and objectives of the user. There are several evaluation methods, including UT, cognitive walkthrough, heuristic reviews, and satisfaction questionnaires. This study chose to use UT as an evaluation method. The steps in UT are as follows [25]:

First, a test plan must be built. Several items needed to be considered in the test plan, including the objectives of the test, RQs, participant characteristics, method, task scenarios, test environment, data collection and analysis, and report presentation. *Second*, the environment must be set up. The pandemic crisis forced us to accomplish the UT in an online environment. Therefore, several tools and devices, such as Zoom and Google Form, were required. Participants were authorised to employ their own personal computer or laptop. Before the test, participants were requested to ensure that their device and internet connection were in good operation.

Third, the participants must be selected. The target users of the prototype were the undergraduate students at one a large and reputable public university in Indonesia. Thirty undergraduate students volunteered to be participants and were chosen randomly.

Fourth, the test materials must be prepared. Several documents were prepared to ensure that the test was directed according to plan, including guidelines for observers, task scenarios, recording consent, and questionnaires. Thirty participants required at least six observers for the test. The observers were teaching assistants of an interaction system course who had knowledge related to UT. Before starting the test, the researcher of the current study conducted a pilot study in which six observers became participants. A pilot study was necessary to assess whether the entire sequence of UT was in accordance with the plan or had failed. Meanwhile, for the observers, the pilot study was considered an orientation. In addition to observing user behaviour, the authors also collected data from the System Usability Scale (SUS) questionnaire, which is one of the most popular surveys used to evaluate usability.

Fifth, the test must be conducted. The test was separated into three sessions. In the first session, or before the test, the observer made sure that all the documents were complete. Then, the observer read the orientation document, the participants filled out the consent form, and the recording began. In the second session, the test took place, and the observer had to obey the dos and don'ts during the test. In the last session, participants were invited to fill out the SUS questionnaire.

Sixth, the collected data must be analysed. The data that were successfully collected were examined based on the evaluation components that were explained in the test plan. The following four aspects were analysed: (1) issues and feedback; (2) task performance; (3) SUS score; and (4) solutions and recommendations for improvement.

Seventh, a report must be generated. The UT results were presented in the form of a UT report, which consisted of a testing plan, issues and feedback, solutions, task performance, and a summary.

3.5 Pilot study

The pilot study aimed to gain an initial picture of the use of learning diaries. This experiment was carried out in the linear algebra course during the short semester of the 2021/2022 academic year. Students were asked to voluntarily use learning diaries. At the beginning of the semester, an orientation of how to compose a learning diary was provided. On a predetermined topic, the lecturer gave the students a reflection task that had to be accomplished using a learning diary. Then, semi-structured interviews were conducted to obtain students' perceptions of the learning diary. The results of the reflection task were analysed using a rubric that had been determined by the linear algebra instructor, while the interview transcripts were analysed using thematic analysis techniques. The result of this experiment was the initial findings about the impact of learning diaries on students' SRL skills.

4 Design research

The literature review was conducted to choose which features should be present in the learning diary. It is important to note that these features must support every phase of SRL. The features in the learning diary are listed in Table 1.

Table 1. Features of Diaria

SRL Phase	Feature	Objective
Forethought	Goal Setting	Students are encouraged to fill in the learning objectives for each topic
Performance	Resources	Students can organise learning resources that come from various sources
	Sticky Notes	Students are encouraged to produce quick notes in the form of sticky notes
	Self-Generated Question	Students are prompted to record questions related to the topic being discussed in class
	Mind Map	Students can transform the concepts they just learned into visual formats, such as mind maps
Self-Reflection	Reflection	At the end of the topic, it is suggested that students reflect on what they have learned, felt, thought, and understood about a certain topic

4.1 Goal setting

Locke and Latham [26] articulated that goals reflect the quantity, quality, and level of performance. The quantity of performance can be measured by how often students are involved in discussions and access the LMS and how long it takes them to understand the concept. For example, students with a mastery orientation usually

spend a lot of time elaborating on a concept, while students with a performance orientation only allocate time to understand the concepts according to their needs. The quality of performance can be observed from how complete the contents of their notes are, how deep their knowledge of a topic is, and how correct their understanding of a concept is. Students with a mastery orientation will attempt to explore a concept more than what is required by the lecturer, while students with a performance orientation feel that the learning resources provided by the lecturer are sufficient.

Goals are valuable for motivating individuals to exercise maximum effort to finish a task and drive individuals to focus on the task, choose the proper strategy, and monitor their progress. Researchers have found empirical evidence of the relationship between goal setting and students' academic success. The positive effects of goal setting include increased self-confidence, higher grade points, and a greater sense of learner autonomy [27]. Goal setting plays an important role in the forethought phase. In this phase, students are asked to set goals and choose fitting strategies that are in accordance with their goals. Both goal setting and strategic planning are affected by the self-motivation beliefs of each student. There is a reciprocal relationship between goal setting and self-efficacy [28]. Students who set goals and monitor their learning progress tend to have high self-efficacy. Personal goals are easier to achieve if students arrange each task that will guide them to accomplish their goals. Each task should have its own timeline so that the students stay on track and can predict when they can reach their goal. In brief, one of the enablers to fulfilling the goals is how students are talented in managing time. For this reason, several techniques for managing time emerged, such as the Pareto principle and the Pomodoro technique. Based on various available literature, which reveals the importance of goals in learning, we propose that goal setting is one of the features that must be available in Diaria.

4.2 Mind map

At the end of 1960s, Tony Buzan popularised a mind-mapping method that strove to activate both hemispheres of the brain. The mind-mapping process begins with a topic in the middle and then adds a collection of ideas that are connected by lines; these ideas then branch off according to the needs of students. Mind maps are helpful for brainstorming; taking notes; consolidating information from various sources; resolving complex problems; presenting information in visual form; learning, storing, and remembering information; and improving innovative and creative thinking as a self-regulation strategy [29]. There is various empirical evidence on the usefulness of mind maps. As summarised by Tanriseven [30], mind maps have a positive effect on student understanding, retention, success, attitude towards courses, learning concepts, motivation, knowledge construction, metacognitive knowledge, and problem-solving.

Mind maps can be operated throughout the SRL phase. For example, in the forethought phase, a mind map can serve as a tool to set goals. Then, each goal has a branch that contains the proper strategy to fulfil each goal. In the performance phase, mind maps can be utilised to monitor the progress of the task. In the reflection phase, the mind map acts as a supporting tool to evaluate the overall goals, selected strategies, and outcomes.

4.3 Note-taking

Note-taking is an SRL strategy. Note-taking has two main functions. First, encoding is a cognitive activity that assists students to understand and remember the material. Second, it is external storage, which refers to the activity of taking notes as a supporting tool for reviewing or revising material [31]. Before the digital age, note-taking was a critical skill for students because information sources were very limited. For example, a lecturer had only one textbook, so students were required to produce summaries as part of external storage. However, nowadays, it is irrelevant because there are multiple sources and formats of information. In fact, this period is also known as the era of information saturation. Therefore, the encoding and external storage functions are no longer relevant for students. Castello and Monereo [32] state that note-taking is not only for encoding and external storage but also for transferring knowledge. Furthermore, students need to know why they need note-taking skills; that is, in some situations, they will be requested to apply the lessons learned from the note-taking experience [33].

4.4 Self-generated questions

The literacy ability of students can be recognised in their ability to generate questions [34]. SGQ is useful for stimulating critical thinking, curiosity, interest, and new ideas; providing a brief description of the misconceptions and knowledge gaps of students [35]; identifying diversity among students; discerning the depth of knowledge construction and cognitive involvement of students; and metacognitively monitoring student understanding. Further, SGQ is related to students' motivational beliefs. The higher the motivation of students, the more they will persistently learn new things, and the more complex the concepts can be. This results in students who can produce high-quality questions [36]. Bates et al. [37] and Jones [38] articulated that SGQ had a positive impact on students' test scores. SGQ has been widely used in science and mathematics and plays an important role in meaningful learning and learning motivation. Chin and Osborne [39] state that questions are a fundamental component of research and problem-solving processes, and students involved in generating questions showed significantly higher cognitive strategies and metacognitive skills.

4.5 Reflection

Turns et al. [40] define reflection as a process where students review certain experiences and evaluate them from various perspectives with the aim of giving meaning to that experience, which will later be used to direct future actions. Hicks et al. [41] proposed the following two reflection activities: first, reflection on experiences such as games, simulations, service learning, or internships; and second, retrospective reflection, which strives to relate previously learned information or experiences to current circumstances and activities, such as mapping or self-evaluation [42]. Turns et al. [40] proposed various elements of reflection, such as experience, lens, meaning, action, intention, and dialectic. In the context of SRL, reflection is the final phase in which students involve self-judgment and self-reaction. This phase is very important to observe whether the predetermined goals have been accomplished. Reflection is valuable in problem-based learning [43] and is used after students successfully solve the problem; they are then asked to retell their experiences, feelings, and knowledge gained from solving the problem. According to Salomon and Perkins [47], in the context of problem-based learning, self-reflection assists students with reviewing the group process, understanding how learning and problem-solving strategies can be re-applied, and linking new knowledge to prior understanding [44].

5 Design prototype

To answer the first research question, a prototype design was carried out. This phase begins with designing the IA to be defined as a model for the collection of information, and the model describes the rules for how the information is presented, accessed, and connected. The IA from the study diary is shown in Figure 2.

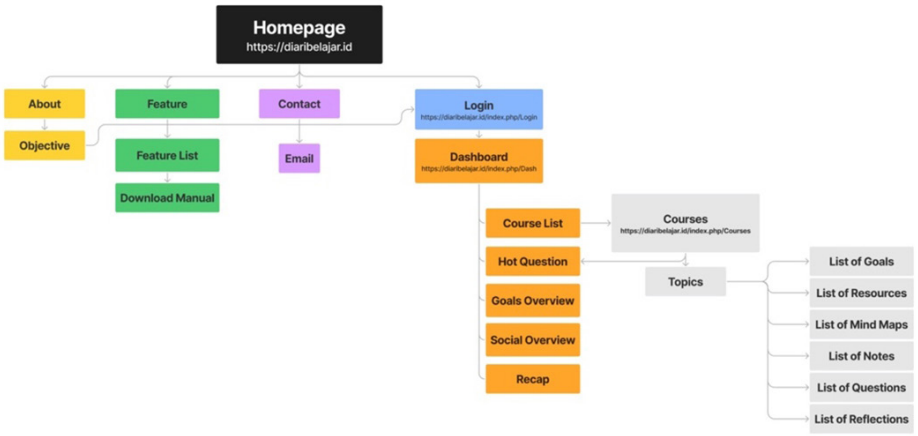

Fig. 2. Information architecture

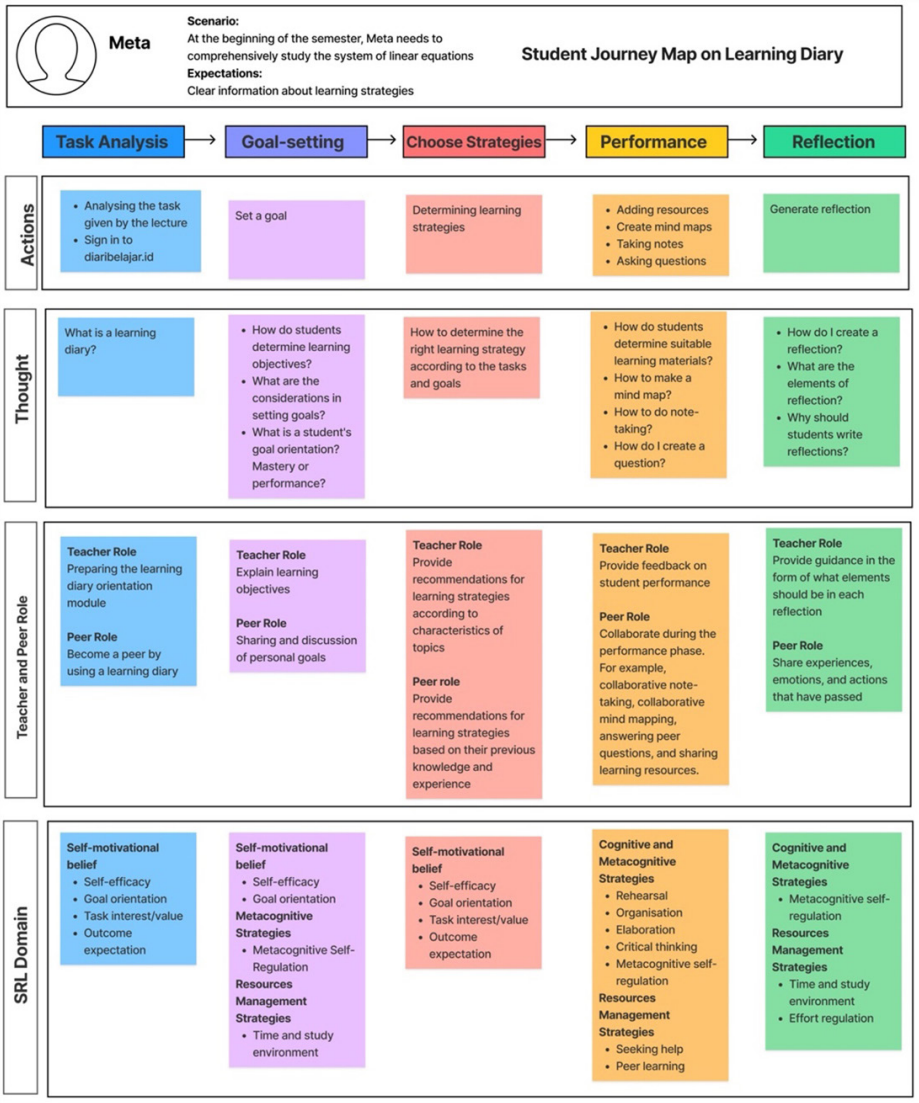

Fig. 3. Student journey map

6 Design evaluation

To answer the second research question, a design evaluation using UT was carried out. UT is a technique to assess a product or system to inform design, eliminate design problems and frustration, and enhance profitability [25]. UT mandates designers to understand the five components of usability quality: memorability, efficiency, errors, learnability, and satisfaction [45].

This UT involved 30 student participants from one a large and reputable public university in Indonesia. These were second-year students and participants in the interaction system class. The interaction system is a course that must be taken in the fourth semester, so they already had knowledge of design principles and UT. The participants were also accustomed to using technology and systems to support learning, such as LMS; in other words, their digital literacy was promising.

The task list comprises those tasks that the participants were asked to perform during the test. The list comprises tasks that would ordinarily be performed in the learning diary. The task list comprises the task number, task description, task scenario, and success criteria, as shown in Table 2.

Table 2. Task list

Task	Description	Scenario	Success Criteria
1	Open Diaria	Open learning diary	Participants successfully logged in using the official account
2	Create a course	Participants added a certain course to their diary	Participants successfully added courses
3	Add a topic	Participants added topics to their course	Participants successfully added topics to the course
4	Set learning goals	Participants created learning goals for each topic	Participants succeeded in adding learning goals to each topic
5	Draw a mind map	Participants drew a mind map related to one of the topics in the courses	Participants successfully added a mind map
6	Ask a question	Participants asked a question about learning material that they did not understand	Participants successfully asked questions
7	Deliver the answer	Participants delivered answers to other participants' questions (if any)	Participants successfully answered other participants' questions
8	Rate the answer	Participants rated other participants' answers (if any)	Participants managed to rate the answers of other participants
9	Rate the question	Participants rated other participants' questions (if any)	Participants managed to rate other participants' questions
10	Produce notes	Participants took notes on a topic they just learned	Participants succeeded in making sticky notes
11	Add learning resources	Participants added files to their diary	Participants successfully added files
12	Create a reflection	Participants constructed a reflection	Participants succeeded in making reflections
13	Visit dashboard	Participants monitored their performance while using a learning diary	Participants successfully visited the dashboard

To guarantee the task was accomplished according to plan, the performance of each task was assessed on the following three levels: failure if the participant terminated the task; success with obstacles if the participant finished the task but there were obstacles; and success if the participant completed the task without issues.

Table 3. Task performance level

State	Description	Score
Failed	If the participant cannot complete the task	1
Success with obstacles	If the participant can complete the task but there were obstacles	2
Success	If the participant can complete the task without problems	3

As shown in Figure 4, the results of the task performance assessment show that Tasks 5, 8, and 13 need attention because the average success score is less than level two. The finding is that participants always struggle when adding mind maps, rating answers from other participants, and interpreting the information available on the dashboard.

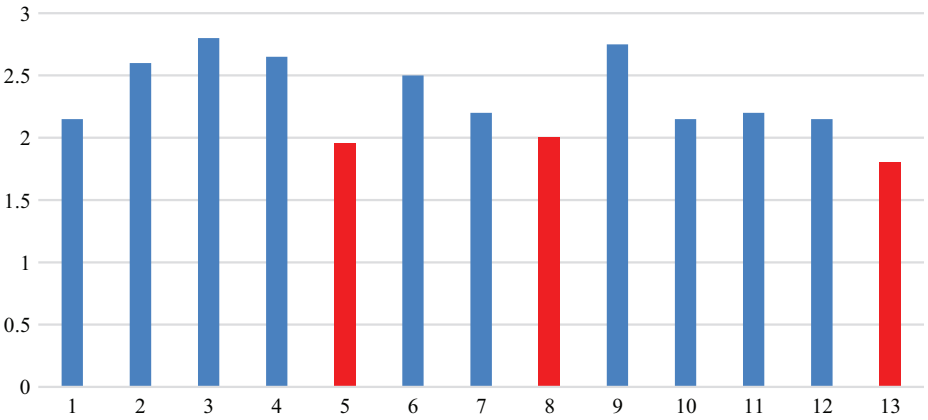

Fig. 4. Task performance

Grouping issues in task completion is critical to facilitating design improvement priorities. Issues are grouped into the following five categories: suggestion, strong suggestion, minor issue, major issue, and blocker issue, as shown in Table 4.

Table 4. Issue categories

Types	Description
Suggestion	Suggestions for improvement, but low importance to participants
Strong Suggestion	Suggestions for improvement for disturbing participants
Minor Issue	Participants stop thinking but keep going
Major Issue	Participants start trial and error
Blocker Issue	Participants give up, only go forward with help

The issues identified during the test were Suggestion (45%), Strong Suggestion (45%), and Major Issues (10%), as shown in Figure 5. Suggestion means that the participants provide suggestions for improvement, but it is of low importance to the participants. For example, participants were asked about the use of start and end dates for courses. Strong Suggestion means that participants provide suggestions for improvement because they feel disturbed by the problem. For example, participants were confused about what a learning diary was. Meanwhile, in Major Issues, participants start trial and error; for example, the participants hesitated when there were questions where the replies will be rated. In this test, we did not discover any Minor Issues or Blocker Issues. This result is promising because it means that there are no obstacles that stop participants from completing the task.

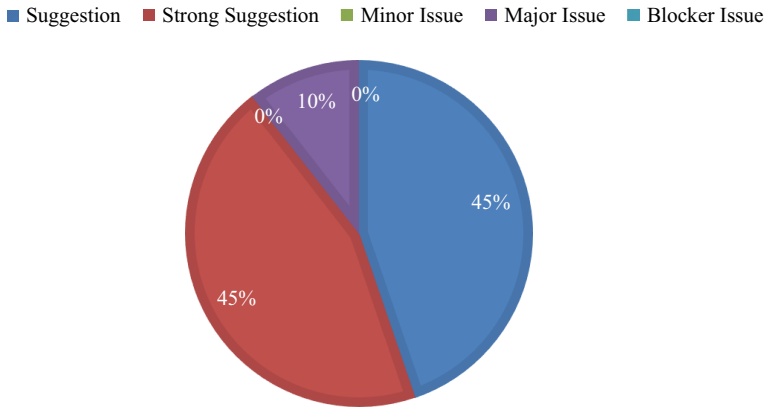

Fig. 5. Issue categories

The problem with Task 1 was that the participants were confused about what a learning diary was. Most of them were annoyed because there was no complete explanation of a learning diary, whereas others thought it was not very important. In Task 1, the participants were asked about the use of start and end dates for courses. Most of the participants did not think this was important. In Task 3, the participants stated that the button to add a new topic should not be placed at the bottom of the page. This is to prevent them from scrolling up. The problem in Task 4 was that the participants hesitated when changing status goals. This was because the icon that was used was unclear. In Task 5, participants were confused about how to add the first node, and some participants even started trial and error. In Tasks 6 and 12, the participants hesitated with a placeholder in the editor, so they struggled with adding questions and reflections. The problem in Task 7 was that the participants were confused and were looking for questions to respond to. Therefore, some of them stated that this was quite disturbing, whereas others stated that it was of low importance. In Task 8, the participants hesitated when they were looking for the questions for which the replies must be rated, so they had difficulty assessing the questions that were already available. The problem in Task 9 was that the participants struggled when searching for questions that already had answers. A small number of participants started trial and error, whereas others felt this was not disturbing enough. In Task 10, most of the participants preferred the sticky notes to be draggable. In Task 11,

the participants were confused by the maximum allowed file size and found it annoying because they had to trial and error. Meanwhile, in Task 13, most of the participants were confused about what performance meant. The grouping of issues for each task is arranged so that the priority of tasks that need to be refined is easy to schedule. As shown in Figure 6, the test results show that more than half of the participants gave suggestions on Tasks 1, 6, 7, 10, 11, 12, and 13. Meanwhile, major issues were found in Tasks 5, 6, 8, 9, 10, and 12, and some participants used trial and error to complete the task.

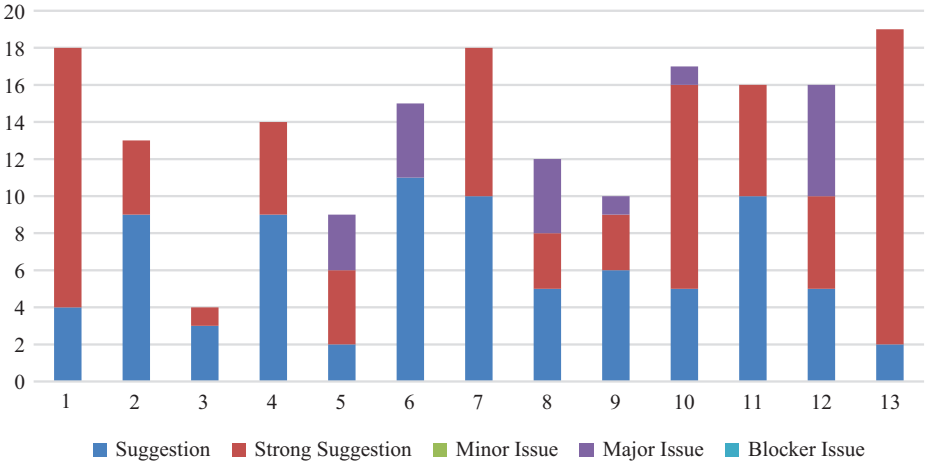

Fig. 6. Issues × tasks

At the end of the UT session, the participants filled out the SUS questionnaire. The questionnaire was used in Bahasa and was put through a series of tests by Sharfina and Santoso [46]. As shown in Figure 7, the SUS score of the learning diary is 73.2, which means the learning diary has good usability.

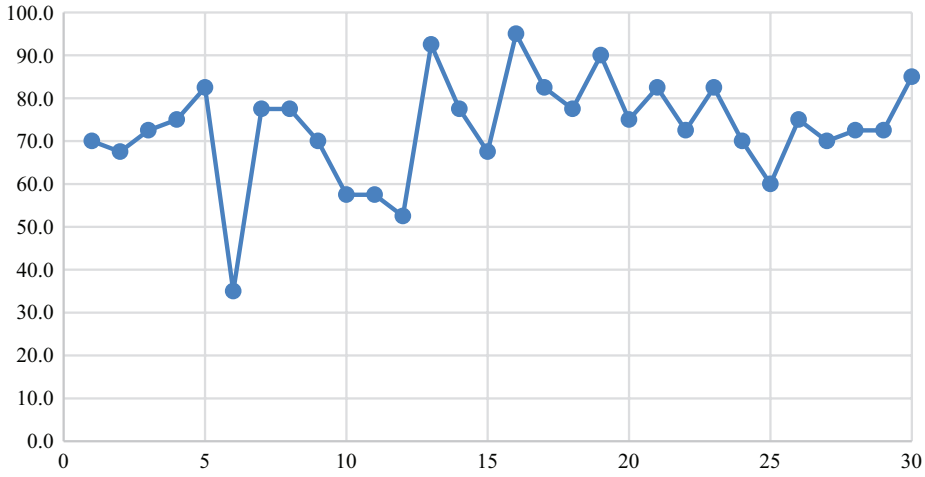

Fig. 7. Distribution of SUS score

Based on the task performance level, issues category, and SUS score, the recommended solutions are arranged as shown in Table 5.

Table 5. Issues and solutions

Task	Description	Issues	Solutions
1	Open learning diary	Participants were confused about what a learning diary was	Prepare a learning diary orientation module
2	Create a course	Participants asked about the use of start and end dates for courses	Remove start and end date options
3	Add a topic	Participants requested that the button to add a new topic was not placed at the bottom of the page	Change the location of the Add New Topics button
4	Set learning goals	Participants hesitated when changing status goals	Change the icon on learning goals
5	Draw a mind map	Participants were confused about how to add the first node	Provide hints and icons
6	Ask a question	Participants hesitated with a placeholder in the editor	Change editor
7	Deliver the answer	Participants were confused when looking for questions to respond to	Allocate Hot Question menu on every page
8	Rate the answer	Participants hesitated when seeking the questions for which the replies must be rated	Provide information on the number of answers available for each question
9	Rate the question	Participants were unsure how to search for questions that already had answers	Allocate Hot Question menu on every page
10	Produce a note	Participants preferred the sticky notes to be draggable	Make sticky notes draggable
11	Add learning resources	Participants were confused by the maximum allowed file size	Provides hints and alerts if the file limit exceeds the limit
12	Create a reflection	Participants were confused by a placeholder in the editor	Change editor
13	Visit dashboard	Participants were confused about what was meant by performance	Provide an explanation of what performance is

7 Design prototype

This preliminary experiment is a pilot study that aims to assess the impact of learning diaries on SRL skills and student performance. The pilot study did not aim to test the hypothesis. However, this experiment is important, as it warns researchers where the main study may fail. This experiment also aims to examine whether the prototype, methods, techniques, tools, instruments, and procedures that have been planned are in accordance with field conditions, needs, and research objectives. In addition, through this experiment, researchers can also determine the necessary time, cost, and human resources for the experiment.

This experiment was carried out in the linear algebra course for the short semester of the 2022/2023 academic year. Linear algebra is a mathematics course at a large and reputable public university in Indonesia. This course equips students with problem-solving skills related to vector algebra and sharpens their mathematical reasoning (logical, consistent, clear, thorough) with a disposition towards critical thinking skills. The participants of this experiment comprised 24 students in the linear algebra course and three teaching assistants. Nineteen students were retaking the course, and five students were new participants in linear algebra.

Experiments were carried out throughout the short semester lectures. As shown in Figure 8, at the first meeting, the students were asked to study the learning diary orientation module in the lesson format available in the Student Centered e-Learning Environment LMS. This module aims to provide students with an understanding of SRL and learning diaries. The module contains a description of the SRL concept, the phases in SRL, and a manual for using a learning diary. Each module section concludes with a quiz of one to two questions. Students were voluntarily asked to use learning diaries to support their learning process.

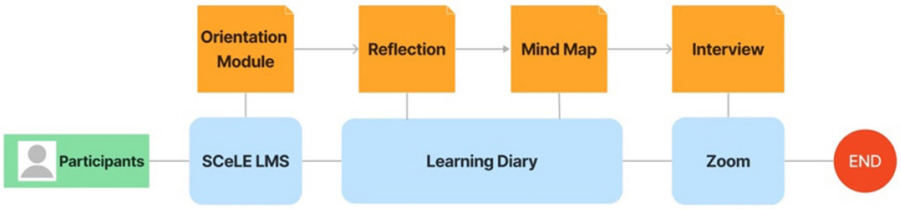

Fig. 8. Procedure

The lecturer gave a reflection task to the participants, in which they were required to use a study diary to complete the task. Descriptions and triggers are provided in Table 6.

Table 6. Reflection task and triggers

Task	Description	Trigger
Reflection 1a	One to two paragraphs that describe the trigger answer	Tell us about your understanding of vectors
Reflection 1b	One to two paragraphs of exposure answer triggers	Describe (1, 2, 3, 0, 6, 11) as a vector
Reflection 1c	Two to four paragraphs that describe the trigger answer	Provide: a. learning experience about vectors; how did your understanding change? b. explain your understanding of vectors, vector spaces, and bases
Concept map	Concept map illustrating the understanding of vector space	Create a concept map that describes vectors, vector spaces, subspaces, bases, and dimensions

Qualitative data were collected through reflection tasks and interviews. Participants were invited to take part in an interview via a class group chat. Interviews were conducted in a semi-structured environment with five course participants and three lecturer assistants either after the mid-term test or approximately a month following the orientation of the learning diary. Given the limitations due to the pandemic, the interview was conducted for around 30 minutes virtually using the Zoom application. At the beginning of the interview, approval was given, including permission to record the interview, protection of the interviewee's personal information, and incentives given for becoming a participant. This interview consisted of six questions that elaborated on expectations and concerns during the lecture, strategies for clarifying concepts that were not yet understood, strategies for improving changes in knowledge, strategies for detecting misconceptions, and participants' perceptions of learning diaries. The qualitative data that were produced were interview transcripts and the results of the reflection task. The interview transcripts were analysed using thematic analysis techniques that produced themes and sub-themes. This technique was assisted by QCAMAP web application to process manual coding. Meanwhile, reflections were analysed using a rubric that was prepared by the linear algebra course lecturers. A thematic analysis of the interview transcripts resulted in several themes and sub-themes, as shown in Table 7.

Table 7. Themes and sub-themes

Themes	Sub-Themes	Example of Participant Statements
Expectation	Grade A	'My target is to become a teaching assistant because at that time, my friend is an assistant lecturer in a linear algebra class, so I hope to get a grade of A'
	Have mathematical knowledge and skills	'So, from the beginning, I really wanted to be serious in the data field. Well, the field requires a lot of concepts that exist in linear algebra. That's what motivated me to seriously study linear algebra'
Concern	Difficult to learn	'My senior said that linear algebra is difficult to learn'
	Unstable motivation	'The concern is that the motivation is lost in the beginning, the enthusiasm then gradually becomes less enthusiastic'
	Failed	'I am worried that I will not pass again because I have taken linear algebra courses in the previous semester'
Clarifying concept understanding	Self-study	'So, try yourself first. First, when I take notes in class, I first check my notes. If it doesn't exist, I'll try to check the presentation slides, then if it's not there, check on YouTube'
	Ask a friend	'If I don't understand, I will ask my friends. If my friends don't understand either, I will ask the teaching assistant and finally the lecturer'
	Ask the teaching assistant	'I often ask the assistant about concepts that I don't understand, but sometimes, I don't feel comfortable asking too many questions'
	Ask the lecturer	'I often email the lecturer if there is a concept that I don't understand because I need a credible answer'
	Reviewing materials	'So, I often see learning video recordings. The video is very helpful, especially for recalling what has been learned'
	Find other learning resources	'I prefer to read books because there are many examples, and the context in the book is clearer'

(Continued)

Table 7. Themes and sub-themes *(Continued)*

Themes	Sub-Themes	Example of Participant Statements
Detect knowledge changes	Face-to-face or virtual discussion with classmates	'So, after the class session, I usually hold a question-and-answer session with my friends. If the explanation is fluent when teaching them, it means that I have understood it, but if I can't explain it fluently, it means that there is something that has not been understood, and usually, after the discussion, I look for which part I do not understand'
	Complete formative assessment	'Because lecturers often give worksheets, I monitor changes in my knowledge from these worksheets. The more questions I can answer, the more I know, and vice versa'
	Visit the discussion forum	'Usually, lecturers give trigger questions in class and in discussion forums. After class, I independently try to answer the trigger questions. If I can answer well, it means I understand the concept, if I still have trouble answering it, it means I must study harder'
	Self-generated question	'I also like to generate my own questions, so the more questions I generate, it means that I still don't understand a lot. But, to make it simpler, I choose one to two key questions, then I look for the answers'
	Note-taking	'Usually, I take notes every weekend, so what I write down is what I remember. So, taking notes helps me know what I know and what I don't know'
Detect misconceptions	Complete the formative assessment	'Every exercise has an example of a solution, so I just must compare my answer with an example of a solution. But if there's no practice or exam that tests my understanding, then I don't know if there's been a misconception'
	Visit the discussion forum	'I often come across misconceptions when I read online discussion forums. So, I was helped by my friend's answer on the forum. When I know there is a misconception, I try to update my notes. I felt compelled to update the notes because I was afraid I would forget what it was really like'
	Face-to-face and virtual discussions with classmates	'I usually know when I listen to other people discussing or explaining. So, I compare my understanding with others. In my opinion, this is the most exciting thing in learning, when our understanding is different from the understanding of others. From that clash of understandings, I learn a lot, because we try to prove each other's understanding'

(Continued)

Table 7. Themes and sub-themes *(Continued)*

Themes	Sub-Themes	Example of Participant Statements
Perception of learning diary	All in one platform	'Fortunately, it is easier for us to check what we have learned, to check the summary, to make mind maps, and to reflect. So, we can make it all in just one application'
	Easy to review material	'The advantage is that you can monitor your understanding with a learning diary. It can help other students too because there is a feature to answer questions and add notes and files, so it's easy to review material'
	Easy to access	'I think it can be accessed from anywhere, if I think of something spontaneously, I just open the application'
	Notes	'I think the most important thing is that it's easy to take notes. So, it's efficient if the notes are in one place, you don't have to bother looking for them anymore. Especially now that people rarely carry books. So, this application is very effective in my opinion'
	Goals	'I also often make targets, even though they are not detailed, but I think they must be recorded, in my opinion'
	Reflection	'The reflection is also useful, in my opinion. So, reflection is per topic, so it will be easy when you want to take an exam'
	Mind Map	'I was helped by the mind map, if you could give an image on the mind map it would be more powerful'
	Self-generated question	'Can save questions that arise during self-study'

The results of the thematic analysis showed that participants had hopes of getting a grade of A and obtaining skills in the field of linear algebra. Participants who wanted to earn a grade of A were motivated by the desire to become lecturer assistants. Meanwhile, participants who wanted to gain skills in the linear algebra field based this on their desire to work in the data field when they graduate from college. This finding is in accordance with the Achievement Goal Theory, which divides students into two groups: mastery, which focuses on skills, and performance, which focuses on grade.

Students also faced concerns at the beginning of the semester. First, the perception was that linear algebra is difficult to learn, as this course is considered a conceptual course and is more abstract compared with other courses. Second, students were concerned that motivation during learning would fluctuate. Third, there was concern of not passing the course, particularly the students who did not pass the linear algebra class in the previous semester.

The results of the analysis show that students have several strategies for clarifying their understanding of a concept. First, if they do not understand a concept, students will independently review their notes, the material provided by educators, and textbooks; re-watch learning videos; and search other sources, such as YouTube. If independent students still face difficulties, the second step is to ask friends. Usually, students discuss face-to-face material either in or after class. If they still have problems after discussing them with friends, the third step is to ask the lecturer's assistant. Students clarify their misunderstanding with the teaching assistant to find a solution to the problem. In the final step, if the lecturer assistant has not succeeded in helping students understand a concept, they will usually ask the educator directly, either in class, via online discussion forums, or via email.

Students have various strategies for detecting changes in their knowledge, the first of which is through discussion with friends. Some students independently create group learning initiatives. In group discussions, each participant will present their own understanding. In this way, participants can detect changes in their knowledge by paying attention to whether they are able to explain their knowledge fluently and whether they are able to answer their group's questions confidently. If students are confident when presenting their understanding and can answer every other group participant, then they will independently assess that there has been a change in their knowledge. The same goes for doing the exercises. If students can answer every question in the exercise without any obstacles, then there has been a change in their knowledge. However, if students are not able to answer all the questions in the exercise, then there has not been a change in the student's knowledge. Trigger questions given by educators in discussion forums are also a tool to detect changes in students' knowledge. Students who can answer trigger questions in both class and online discussion forums have experienced a change in their knowledge. Another way to detect changes in knowledge is to take notes. Students who take notes completely and efficiently without the help of other learning resources such as books and video recordings have experienced changes in knowledge. The last strategy is to answer all SGQs. When learning, students often ask questions about aspects that they do not understand. Students can detect changes in their knowledge by answering all the questions they have compiled. The more questions they can answer, the more knowledge they will have gained.

Further, students have various strategies to detect misconceptions. First, students will find misconceptions when doing the exercises. Students can see the solutions from the exercises and then compare them with their own solutions. In this situation, students will detect whether they have experienced misconceptions. Second, students are encouraged to look at the discussion forums. Lecturers provide trigger questions in discussion forums, and students provide answers in these forums. Students can detect misconceptions when they see answers from classmates. Misconceptions can also be detected directly when discussing with friends face-to-face, namely by comparing the explanations from their peers with their own understanding.

The results of the analysis also show that learning diaries have various advantages. First, students think that a learning diary can be a platform in which they can set goals, manage learning resources, take notes, record questions, make mind maps, and create reflections. Second, it is very accessible; web-based learning diaries can be accessed anywhere and anytime via the internet. This ease of access allows students to use learning diaries spontaneously to support the learning process. Third, it makes it easier

for students to review the learning material. It can be accessed anytime and anywhere and is consolidated into a single platform, making it easy for students to review the predetermined goals, summaries of each topic, learning reflections, mind maps, and questions that have not been answered by students.

The results of the analysis show that the features contained in the learning diary can support the learning process. The goal-setting feature allows students to set goals at the beginning of the semester for each topic. The note-taking feature can be used by students to make summaries, both when studying independently and when studying in class, making it easier for them to review the material they have learned. This feature is very helpful for students in clarifying concepts they do not understand. The mind-map feature will help students summarise notes in visual form and is very helpful for students to detect changes in their knowledge. The SGQ feature allows students to record questions while studying independently and helps students detect misconceptions. The reflection feature allows students to reflect on the learning material and apply it to everyday life or other contexts.

8 Conclusion and future direction

Researchers agree that SRL skills are essential to improve academic performance. The importance of SRL skills applies to all levels of education and educational settings. In the field of computer science, the topic of SRL is the centre of discussion. This study aimed to develop Diaria to enhance SRL skills. The learning diary also took part in the third wave of SRL measurement as a tool that played a role in both measuring and intervening in the SRL strategy.

Diaria had several features, including learning goals, resources, mind maps, SGQs, sticky notes, and reflections, and each feature represented each phase of the SRL. The resulting high-fidelity prototype was evaluated using the UT method. The result of the evaluation is the SUS score of 73.2, which indicates good usability with some suggestions from participants for ways to enhance the prototype.

There were several findings in the pilot study. The students expected to get an A and improve their math skills. Meanwhile, they were worried that linear algebra would be difficult to learn or that they would fail, resulting in unstable motivation. We also found that students had strategies to clarify their understanding, such as self-study; asking friends, lecturer assistants, and lecturers; and looking for other learning resources. They also had various strategies for detecting changes in knowledge by engaging in both face-to-face and virtual discussions with classmates, completing formative assessments and SGQs, and note-taking. Students also had strategies for detecting misconceptions, again by engaging in both face-to-face and virtual discussions with classmates, completing formative assessments, and SGQs. Students stated that the learning diary was easily accessible, helped them to review material, was an all-in-one platform, and its features were very helpful in improving their understanding, detecting changes in knowledge, and highlighting misconceptions.

Based on these findings, the following is a proposed scenario for the use of Diaria that can be seen in several contexts. The first is synchronous and asynchronous methods. Learning diaries can be used in synchronous methods, such as in classrooms and virtual classes to take notes, save questions, or create mind maps. In asynchronous methods,

such as watching recorded videos or viewing discussions in online forums, study diaries can also be used to take notes, save questions, or create mind maps.

The second is the flipped learning method. Learning diaries can be used before face-to-face classes or virtual classes take place by managing learning resource files, making initial notes, and answering questions that arise during self-study. Learning diaries can also be used when face-to-face or virtual classes are in progress by perfecting notes, managing questions related to learning materials, and clarifying confusion experienced during self-study. Further, learning diaries can be used after face-to-face classes or virtual classes take place by correcting notes, making mind maps of concepts that have been studied, reviewing learning materials, and making summaries.

The third is formal, informal, and non-formal education. Learning diaries can be used in various forms of education. In formal education, such as in universities, learning diaries can be used in face-to-face classes or virtual classes. Additionally, learning diaries can be used to take notes from lecturer presentations in the classroom, formulate questions about learning materials, and make summaries from discussion forums available on the LMS. In informal education, learning diaries can be used to take notes when watching learning videos on YouTube or to make summaries during group study. Further, learning diaries can be used in non-formal education, such as making mind maps and creating summaries of learning videos that are available on the MOOC platform.

This experiment was only carried out in one class of linear algebra courses, so the findings cannot be directly generalised. Students in this course were also dominated by students retaking the course, and this warrants further study. The short lecture time and the motivation not to fail again inhibit the students from exploring the usefulness of learning diaries. In this experiment, it was found that there were technical limitations in the learning diary, which was related to the mathematical notation editor. The findings and constraints of this pilot study will be valuable for the main study.

9 References

[1] B. P. Sahoo, A. Gulati, and I. U. Haq, 'Covid 19 and challenges in higher education: An empirical analysis,' *International Journal of Emerging Technologies in Learning,* vol. 16, no. 15, pp. 210–225, 2021. https://doi.org/10.3991/ijet.v16i15.23005

[2] J. S. Barrot, I. I. Llenares, and L. S. del Rosario, 'Students' online learning challenges during the pandemic and how they cope with them: The case of the Philippines,' *Education and Information Technologies,* vol. 26, no. 6, pp. 7321–7338, 2021. https://doi.org/10.1007/s10639-021-10589-x

[3] B. J. Zimmerman, 'A social cognitive view of self-regulated academic learning,' *Journal of Educational Psychology,* vol. 81, no. 3, pp. 329–339, 1989. https://doi.org/10.1037/0022-0663.81.3.329

[4] L. Anthonysamy, A. C. Koo, and S. H. Hew, 'Self-regulated learning strategies in higher education: Fostering digital literacy for sustainable lifelong learning,' *Education and Information Technologies,* vol. 25, pp. 2393–2414, 2020. https://doi.org/10.1007/s10639-020-10201-8

[5] H. N. Haron, H. Harun, R. Ali, K. R. Salim, and N. H. Hussain, 'Self-regulated learning strategies between the performing and non-performing students in statics,' in *International Conference on Interactive Collaborative Learning,* Dubai, United Arab Emirates, 2014. https://doi.org/10.1109/ICL.2014.7017875

[6] C. L. Scott, 'The futures of learning 2: What kind of learning for the 21st century?' in *Education Research and Foresight Working Papers,* 14 pages, 2015.

[7] A. Ejubovic and A. Puška, 'Impact of self-regulated learning on academic performance and satisfaction of students in the online environment,' *Knowledge Management and E-Learning,* vol. 11, no. 3, pp. 345–363, 2019. https://doi.org/10.34105/j.kmel.2019.11.018

[8] H. Castellanos, F. Restrepo-Calle, F. A. Gonzalez, and J. J. R. Echeverry, 'Understanding the relationships between self-regulated learning and students source code in a computer programming course,' in *IEEE Frontiers in Education Conference (FIE),* 2017. https://doi.org/10.1109/FIE.2017.8190467

[9] V. Kumar, P. Winne, A. Hadwin, J. Nesbit, D. Jamieson-Noel, T. Calvert, and B. Samin, 'Effects of self-regulated learning in programming,' in *International Conference on Advanced Learning Technologies,* 2005. https://doi.org/10.1109/ICALT.2005.131

[10] E. Panadero, J. Klug, and S. Järvelä, 'Third wave of measurement in the self-regulated learning field: When measurement and intervention come hand in hand,' *Scandinavian Journal of Educational Research,* vol. 60, no. 6, pp. 723–735, 2016. https://doi.org/10.1080/00313831.2015.1066436

[11] B. Cenka, H. Santoso, and K. Junus, 'Using the personal learning environment to support self-regulated learning strategies: A systematic literature review,' *Interactive Learning Environments,* 2022. https://doi.org/10.1080/10494820.2022.2120019

[12] C. L. Lim, H. A. Jalil, A. M. Marof, and W. Z. Saad, 'Peer learning, self-regulated learning and academic achievement in blended learning courses: A structural equation modeling approach,' *International Journal of Emerging Technologies in Learning,* vol. 15, no. 3, pp. 110–125, 2020. https://doi.org/10.3991/ijet.v15i03.12031

[13] J. Ceron, S. Baldiris, J. Quintero, R. R. Garcia, G. L. V. Saldarriaga, S. Graf, and L. D. L. Fuente Valentin, 'Self-regulated learning in massive online open courses: A state-of-the-art review,' *IEEE Access,* vol. 9, pp. 511–528, 2021. https://doi.org/10.1109/ACCESS.2020.3045913

[14] V. S. Silverajah, S. L. Wong, A. Govindaraj, M. N. M. Khambari, R. W. B. O. Rahmat, and A. R. M. Deni, 'A systematic review of self-regulated learning in flipped classrooms: Key findings, measurement methods, and potential directions,' *IEEE Access,* vol. 10, pp. 20270–20294, 2022. https://doi.org/10.1109/ACCESS.2022.3143857

[15] R. A. Carter, M. Rice, S. Yang, and H. A. Jackson, 'Self-regulated learning in online learning environments: Strategies for remote learning,' *Information and Learning Science,* vol. 121, no. 5–6, pp. 311–319, 2020. https://doi.org/10.1108/ILS-04-2020-0114

[16] B. Schmitz and B. S. Wiese, 'New perspectives for the evaluation of training sessions in self-regulated learning: Time-series analyses of diary data,' *Contemporary Educational Psychology,* vol. 31, no. 1, pp. 64–96, 2006. https://doi.org/10.1016/j.cedpsych.2005.02.002

[17] B. Schmitz and F. Perels, 'Self-monitoring of self-regulation during math homework behaviour using standardized diaries,' *Metacognition and Learning,* vol. 6, no. 3, pp. 255–273, 2011. https://doi.org/10.1007/s11409-011-9076-6

[18] O. Clipa, A. A. Ignat, and M. Stanciu, 'Learning diary as a tool for metacognitive strategies development,' *Procedia – Social and Behavioral Sciences,* vol. 33, pp. 905–909, 2012. https://doi.org/10.1016/j.sbspro.2012.01.253

[19] C. D.-v. Ewijk, S. Fabriz, and G. Büttner, 'Fostering self-regulated learning among students by means of an electronic learning diary: A training experiment,' *Journal of Cognitive Education and Psychology,* vol. 14, no. 1, pp. 77–97, 2015. https://doi.org/10.1891/1945-8959.14.1.77

[20] J. Broadbent, E. Panadero, and M. Fuller-Tyszkiewicz, 'Effects of mobile-app learning diaries vs online training on specific self-regulated learning components,' *Educational Technology Research and Development,* vol. 68, no. 5, pp. 2351–2372, 2020. https://doi.org/10.1007/s11423-020-09781-6

[21] J. J. Garrett, *The Element of User Experience: User-Centered Design for the Web and Beyond,* Berkeley, CA, USA: New Riders: Pearson Education, 2010.
[22] H. B. Santoso, P. O. Putra, and F. F. H. S. Febrian, 'Development & evaluation of e-learning module based on visual and global preferences using a user-centered design approach,' *International Journal of Emerging Technologies in Learning,* vol. 16, no. 15, pp. 139–151, 2021. https://doi.org/10.3991/ijet.v16i15.24163
[23] A. Williams, 'User-centered design, activity-centered design, and goal-directed design: A review of three methods for designing web applications,' in *ACM Special Interest Group for Design of Communications,* Bloomington, 2009. https://doi.org/10.1145/1621995.1621997
[24] M. Bødker, 'Performative artefacts: Users "speaking through" artefacts in collaborative design,' in *Proceedings of the 21st Annual Conference of the Australian Computer-Human Interaction Special Interest Group Design Open,* Melbourne, 2009. https://doi.org/10.1145/1738826.1738830
[25] J. Rubin and D. Chisnell, *Handbook of Usability Testing, Second Edition: How to Plan, Design, and Conduct Effective Tests,* Indianapolis, Indiana, USA: Wiley, 2008.
[26] E. A. Locke and G. P. Latham, *A Theory of Goal Setting and Task Performance,* New Jersey, USA: Prentice-Hall, 1990.
[27] M. Bloom, 'Self-regulated learning: Goal setting and self-monitoring,' *The Language Teacher, the Japan Association for Language Teaching,* vol. 37, no. 4, pp. 46–50, 2013. https://doi.org/10.37546/JALTTLT37.4-6
[28] B. J. Zimmerman, 'Self-regulated learning and academic achievement: An overview,' *Educational Psychologist,* vol. 25, no. 1, pp. 3–17, 1990. https://doi.org/10.1207/s15326985ep2501_2
[29] S. O. Adodo, 'Effect of mind-mapping as a self-regulated learning strategy on students' achievement in basic science and technology,' *Mediterranean Journal of Social Sciences,* vol. 4, no. 6, pp. 163–172, 2013. https://doi.org/10.5901/mjss.2013.v4n6p163
[30] I. Tanriseven, 'A tool that can be effective in the self-regulated learning of pre-service teachers: The mind map,' *Australian Journal of Teacher Education,* vol. 39, no. 1, pp. 65–80, 2014. https://doi.org/10.14221/ajte.2014v39n1.1
[31] J. van der Meer, 'Students' note-taking challenges in the twenty-first century: Considerations for teachers and academic staff developers,' *Teaching in Higher Education,* vol. 17, no. 1, pp. 13–23, 2012. https://doi.org/10.1080/13562517.2011.590974
[32] M. Castelló and C. Monereo, 'Students' note-taking as a knowledge-construction tool,' *Educational Studies in Language and Literature,* vol. 5, no. 3, pp. 265–285, 2005. https://doi.org/10.1007/s10674-005-8557-4
[33] J. Hattie, J. Biggs, and N. Purdie, 'Effects of learning skills interventions on student learning: A meta-analysis,' *Review of Educational Research,* vol. 66, no. 2, pp. 99–136, 1996. https://doi.org/10.3102/00346543066002099
[34] L. Maplethorpe, H. Kim, M. R. Hunte, M. Vincett, and E. E. Jang, 'Student-generated questions in literacy education and assessment,' *Journal of Literacy Research,* vol. 54, no. 1, pp. 74–97, 2022. https://doi.org/10.1177/1086296X221076436
[35] C. Chin, D. E. Brown, and B. C. Bruce, 'Student-generated questions: A meaningful aspect of learning in science,' *International Journal of Science Education,* vol. 24, no. 5, pp. 521–549, 2002. https://doi.org/10.1080/09500690110095249
[36] G. Botsas and S. Padeliadu, 'Goal orientation and reading comprehension strategy use among students with and without reading difficulties,' *International Journal of Educational Research,* vol. 39, no. 4–5, pp. 477–495, 2003. https://doi.org/10.1016/j.ijer.2004.06.010
[37] S. P. Bates, R. K. Galloway, J. Riise, and D. Homer, 'Assessing the quality of a student-generated question repository,' *Physical Review Special Topics – Physics Education Research,* vol. 10, no. 1, pp. 1–24, 2014. https://doi.org/10.1103/PhysRevSTPER.10.020105

[38] J. A. Jones, 'Scaffolding self-regulated learning through student-generated quizzes,' *Active Learning in Higher Education,* vol. 20, no. 2, pp. 115–126, 2019. https://doi.org/10.1177/1469787417735610
[39] C. Chin and J. Osborne, 'Students' questions: A potential resource for teaching and learning science,' *Studies in Science Education,* vol. 44, no. 1, pp. 1–39, 2008. https://doi.org/10.1080/03057260701828101
[40] J. A. Turns, B. Sattler, K. Yasuhara, J. L. Borgford-Parnell, and C. J. Atman, 'Integrating reflection into engineering education,' in *ASEE Annual Conference and Exposition, Conference Proceedings,* Indianapolis, Indiana, 2014.
[41] N. Hicks, A. E. Bumbaco, and E. P. Douglas, 'Critical thinking, reflective practice, and adaptive expertise in engineering,' in *ASEE Annual Conference & Exposition,* Indianapolis, Indiana, 2014.
[42] L. A. Sepp, M. Orand, J. A. Turns, L. D. Thomas, B. Sattler, and C. J. Atman, 'On an upward trend: Reflection in engineering education,' in *ASEE Annual Conference and Exposition,* Seattle, WA, 2015.
[43] C. E. Hmelo-Silver, 'Problem-based learning: What and how do students learn?' *Educational Psychology Review,* vol. 16, no. 3, pp. 233–266, 2004. https://doi.org/10.1023/B:EDPR.0000034022.16470.f3
[44] M. D. Lew and H. G. Schmidt, 'Self-reflection and academic performance: Is there a relationship?' *Advances in Health Sciences Education,* vol. 16, no. 4, pp. 529–545, 2011. https://doi.org/10.1007/s10459-011-9298-z
[45] J. Nielsen, 'Usability 101: Introduction to usability,' Nielsen Norman Group, January 3, 2012. [Online]. Available: https://www.nngroup.com/articles/usability-101-introduction-to-usability/. [Accessed 02 2022].
[46] Z. Sharfina and H. B. Santoso, 'An Indonesian adaptation of the system usability scale (SUS),' in *ICACSIS 2016,* 2016. https://doi.org/10.1109/ICACSIS.2016.7872776
[47] G. Salomon and D. N. Perkins, 'Rocky roads to transfer: Rethinking mechanisms of a neglected phenomenon,' *Educational Psychologist,* vol. 24, no. 2, pp. 113–142, 1989. https://doi.org/10.1207/s15326985ep2402_1
[48] E. Araka, E. Maina, R. Gitonga, and R. Oboko, 'Research trends in measurement and intervention tools for self-regulated learning for e-learning environments—systematic review (2008–2018),' *Research and Practice in Technology Enhanced Learning,* vol. 15, no. 1, 2020. https://doi.org/10.1186/s41039-020-00129-5
[49] W. Matcha, N. A. Uzir, D. Gasevic, and A. Pardo, 'A systematic review of empirical studies on learning analytics dashboards: A self-regulated learning perspective,' *IEEE Transactions on Learning Technologies,* vol. 13, no. 2, pp. 226–245, 2020. https://doi.org/10.1109/TLT.2019.2916802
[50] R. Mahajan, D. K. Badyal, P. Gupta, and T. Singh, 'Cultivating lifelong learning skills during graduate medical training,' *Medical Education,* vol. 53, no. September, pp. 797–804, 2016. https://doi.org/10.1007/s13312-016-0934-9

10 Authors

Baginda Anggun Nan Cenka, Universitas Indonesia, Depok City, West Java, Indonesia.
Harry B. Santoso, Universitas Indonesia, Depok City, West Java, Indonesia.
Kasiyah Junus, Universitas Indonesia, Depok City, West Java, Indonesia.

Article submitted 2022-09-25. Resubmitted 2023-02-13. Final acceptance 2023-02-22. Final version published as submitted by the authors.