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General Section

Metadig: an application for self-regulated learning in distance education

Metadig: una aplicación para el aprendizaje autorregulado en educación a distancia

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ABSTRACT

Metadig application has been designed and developed to facilitate self-regulated learning through metacognitive strategies in distance higher education teacher training. This study support application is based on the results gathered from a previous version of the application. On the one hand, based on how to pedagogically structure the support of metacognitive strategies, for which three basic functions are distinguished: goal selection and planning, monitoring, and self-assessment. On the other hand, improving the ease and suitability of use through validation by experts. In addition to incorporating all these proposals for improvement, this article provides a new study on the needs detected in the capacity for self-regulation in reading comprehension, study habits and the use of critical thinking in 252 trainee teachers. In this way, the design process and the resulting development is based on both previous studies and how it can improve these three aspects (reading comprehension, study habits and critical thinking). It is concluded that a more suitable and user-friendly version has been obtained, and that it will improve the application of metacognitive strategies for self-regulated learning in terms of reading comprehension, study habits and critical thinking.

RESUMEN

La aplicación Metadig ha sido diseñada y desarrollada para facilitar el aprendizaje autorregulado a través de estrategias metacognitivas en la formación del profesorado de educación superior a distancia. Esta aplicación de apoyo al estudio se basa en los resultados recogidos de una versión anterior de la aplicación. Por un lado, basándose en cómo estructurar pedagógicamente el apoyo de estrategias metacognitivas, para lo que se distinguen tres funciones básicas: selección y planificación de objetivos, monitorización y autoevaluación. Por otro lado, mejorando la facilidad e idoneidad de uso a través de la validación por expertos. Además de incorporar todas estas propuestas de mejora, este artículo aporta un nuevo estudio sobre las necesidades en la capacidad de autorregulación en comprensión lectora, hábitos de estudio y uso del pensamiento crítico en 252 profesores en formación. Así, el proceso de diseño y el desarrollo resultante se basa tanto en estudios previos como en la forma en que puede mejorar estos aspectos (comprensión lectora, hábitos de estudio y pensamiento crítico). Se concluye que se ha obtenido una versión más adecuada y fácil de utilizar, que mejorará la aplicación de estrategias metacognitivas para el aprendizaje autorregulado respecto a comprensión lectora, hábitos de estudio y pensamiento crítico.

KEYWORDS - *PALABRAS CLAVE*

Self-regulated learning, metacognition, application design, distance education

Aprendizaje autorregulado, metacognición, diseño de aplicaciones, educación a distancia

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1. INTRODUCTION

Self-regulated learning is mainly composed of cognitive, metacognitive, and socioemotional strategies, according to the proposals of different experts in the field (Panadero, 2017). Muijs and Bokhove (2020) carry out an updated review of the main components of metacognition through different proposals and paradigms, concluding three essential components to regulate cognition: planning, which refers to goal setting, activation of relevant prior knowledge, selection of appropriate strategies and allocation of resources; monitoring, highlighting self-assessment activities, necessary to control the learning process during its execution; and evaluation, which refers to the assessment of results and regulatory processes of learning itself.

Metacognitive strategies promote the use of cognitive strategies. Monitoring, defined by strategies that favor reflection on the learning process, and perceived self-efficacy promote cognitive strategy use. Therefore, to improve students' self-regulated learning, it is essential to emphasize metacognitive strategies and self-efficacy in self-regulated learning interventions (Akamatsu, et al., 2019).

To facilitate the use of self-regulated learning by students, specific tools have been developed, for example, through synchronous writing services in videoconferencing tools such as Zoom (Harwood and Koyama, 2020), through the visualization of notes and notes of peers (Yokoyama, et al., 2020), or even external support tools such as nStudy (Winne and Hadwin, 2013) that facilitate the underlining of texts, the creation of concept maps, notes or labels. All these tools are aimed at supporting cognitive strategies.

For the online modality, as is the case of massive open online courses (MOOCs), where there are no face-to-face sessions to guide self-regulated learning, it is more important to provide tools that facilitate this self-regulation (Albelbisi, 2019), and there are already some proposals in this regard (Jansen, et al., 2020), including tools that can be integrated into these courses, such as NoteMyProgress (Pérez-Álvarez, et al., 2017; 2018a). Most studies in this context conclude that the use of interactive visualizations favors self-regulated learning, and that social comparison impacts positively on engagement and time management (Pérez-Álvarez, et al., 2018b).

However, most technological tools to support self-regulated learning focus on cognitive strategies, as we have already seen, with tools to support metacognitive and motivational strategies taking a back seat (Devolder, et al., 2012; Hooshyar, et al., 2020), although some tools attempt to complement both types of strategies. One example is a metacognitive learning management system created by Zarouk and Khaldi (2016), which combines cognitive strategies with planning, monitoring and evaluation. Another example is MetaTutor (Azevedo, et al., 2010) which distinguishes between cognitive and metacognitive strategies, the latter including planning and monitoring tasks.

Other tools that support metacognitive strategies include tools aimed at facilitating reflection of feedback in formative assessment (Caeiro-Rodriguez, et al., 2016; Usart-Rodriguez, et al., 2021), metacognitive questioning tools (Kahn, et al., 2016; Kramarski and Gutman, 2006), including tools with adaptive questioning (Dascalu, et al., 2017), goal-setting tools (Thomas, et al., 2016), graphical task organizer-type tools to facilitate planning and monitoring in writing (Hughes, et al., 2019), or those based on job evaluation (Piotrkowicz, et al., 2018).

Although we see varied examples, the development of these tools is difficult because the validation of educational technology is complex, due to the difficulty of basing all development steps on a single sound scientific theory. For this reason, it is recommended to rely on a framework that combines the search for relevant literature with expert consultation (de Klerk, et al., 2018). In the specific case of self-regulated learning, it is important to consider what needs to be considered when designing learning management systems based on these factors. A tool that facilitates self-regulated learning should meet all these characteristics seen so far: it should be mainly based on supporting metacognitive strategies (goal selection and planning, monitoring, and self-assessment), and it should also suggest different cognitive strategies so that learners can choose which one they find most appropriate depending on which goal they want to work on.

For a well-designed online course, Van Laer and Elen (2017) review previous research and conclude seven attributes that improve self-regulated learning in online environments: (1) authenticity, (2) personalized selection of task, (3) control of the learner in selection of tasks, (4) assistance for guiding learners towards goals, (5) scaffolding of complex tasks to ease cognitive load, (6) feedback to enable reflection, (7) peers interaction.

Moreover, Bull and Kay (2019) propose the Open Learner Model (OLM) to include questions that facilitate metacognitive strategies for self-regulated learning: what do I know, what do I want to know, and how can I get it (Kay et al., 1997). OLM has been found to produce improvements in reflecting on their learning process in blended models in higher education (Hooshyar et al., 2019). In addition, tools such as goal setting and strategy implementation, strategy tracking, and performance monitoring have been found to develop self-regulated learning (Chou and Zou, 2020).

In addition, OLM should include support for the three types of strategies that have been posited as essential in self-regulated learning: planning, monitoring, and self-assessment (Muijs and Bokhove, 2020). Planning, and more specifically time management, weighs heavily on performance (Fokkens-Bruinsma, et al., 2020). As such, performance can be enhanced if learners adopt planning and time management strategies (Colthorpe, et al., 2018).

According to the results of Ortega-Ruipérez and Castellanos (2023), a tool focused on metacognitive strategies should focus on improving knowledge of objectives and evaluation criteria, as part of planning; on the ability to recognize when a goal is acquired and thus be able to modify initial plans, as part of monitoring; on expending additional effort studying hard subjects and acquiring different cognitive strategies for study, as part of self-evaluation. In addition, it should facilitate the control of study time. In relation to this, Ortega-Ruipérez and Castellanos (2021) create a first version of the tool following the findings. This tool is validated by experts, who suggest simplifying the introduction of objectives and planning, as well as the possibility of re-planning during the supervision phase. The inclusion of activities as learning objectives is also suggested to take them into account in planning and supervision (Ortega-Ruipérez and Castellanos, n.p.).

In addition to the results obtained so far, it is important to consider the relationship of self-regulated learning with the improvement of different aspects directly involved in learning, so that they can be considered in the design of the app.

In terms of improving these components of learning, reading comprehension has obtained the greatest effects in intervention programs (Carretti, et al., 2014), since according to the results of Soodla, et al. (2016) reading comprehension improves if the metacognitive knowledge of reading strategies is worked on. Furthermore, according to Vázquez-López and Huerta-Manzanilla (2021) conclude from the results of PISA 2018, the use of metacognitive strategies is one of the variables with the greatest weight in explaining reading proficiency (Vázquez-López and Huerta-Manzanilla, 2021). Therefore, to measure the influence of self-regulated learning on reading comprehension, Núñez et al. (2015) validated a scale for the assessment of self-regulated learning from texts or ARATEX-R with university students. The use of the first version of the application (APP) especially improved motivation management, comprehension assessment and planning (Ortega-Ruipérez, 2022).

Metacognitive strategies are general to all types of tasks and transferable, and therefore require support from teachers for their transfer, as it is difficult for students to transfer them to other domains (Schuster, et al., 2020). This aspect calls for the need to make metacognitive strategies explicitly included so that learners can incorporate them into their learning process (Dignath and Veenman, 2021). Moreover, cognitive mediation by teachers is an indispensable resource for students' progress in autonomy and metacognition processes, with the goal of achieving self-regulated learning (Ferreira, et al., 2019). Teachers should foster a culture of inquiry to promote autonomy in learning, focusing on thinking skills (Dobber, et al., 2017). This autonomy will lead to an improvement in academic performance by improving study habits (Cleary, 2006). For this reason, Cleary (2006) developed and validated the Self- Regulation Strategy Inventory-Self-Report (SRSI-SR) questionnaire, which assesses in a simple way four dimensions of how self-regulated learning influences study habits. The use of the first version of the app especially improved task organization (Ortega-Ruipérez, 2022).

Less has been studied about critical thinking as a basic component for learning. Critical thinking involves reasoning and decision making, so many studies assess critical thinking through these two basic aspects of thinking. For example, the PENCRISAL test (Rivas and Saiz, 2012), the most widely used test in Spanish to measure critical thinking in adults, includes several dimensions of reasoning (inductive, deductive, and practical), as well as measuring problem solving and decision-making. Even with a well-founded theoretical approach, critical thinking is difficult to measure, because situations have to be presented in the tests that serve to measure everyday critical thinking, and not applied to a specific field. One approach is to measure critical thinking in relation to basic thinking, as in Critical Thinking Questionnaire (Santiuste et al., 2001).

On the other hand, in relation to teaching, the need to study why teachers should be experts in metacognitive strategies to teach their students has been called for a long time (Duffy, et al., 2009). Teachers need to start applying self-regulated learning strategies to improve their students' learning and skills (Panadero, 2017). A study by Soodla, et al. (2016) highlights the importance of teachers having good metacognitive knowledge to improve students' metacognitive knowledge. Furthermore, teachers' own beliefs about the benefits of applying strategies for self-regulated learning and students' ability to apply them are significant predictors of teachers' ability to apply these strategies (Yan, 2017). In this sense, it is necessary to investigate further the relationship between the motivation to use these strategies and teachers' beliefs about introducing these strategies in the classroom. Lombaerts et al. (2009) highlighted the importance of considering teachers' beliefs to understand their interest in including them in the classroom.

It is also important to consider developments in learning theories in order to design teacher education to include metacognitive practices (Muijs, et al., 2014), as evidence suggests that not all teacher education is successful (Corcoran and O'Flaherty, 2017). Therefore, teacher trainings should include well-designed concrete strategies to manage self-regulated learning through metacognition, as these trainings enhance self-efficacy to foster self-regulated learning and its perception in practice (Dignath, 2021). On this point, de Smul, et al. (2018) have already considered the importance of relating teachers perceived self-efficacy to implement self-regulated learning strategies.

The aim is to design and develop the app that facilitates the use of metacognitive strategies in distance teacher training. To this end, the design will be based on the knowledge acquired so far with the first version of the app, on the one hand, and on the study of the needs regarding the use of strategies for the self-regulation of reading comprehension, study habits and the use of critical thinking, on the other hand.

2. METHOD

2.1. Research Design

The aim of this article is to deepen the new and definitive design of the app Metadig for the use of metacognitive strategies for the self-regulation of teachers who are being trained at a distance.

To this end, prior to the design of the app, descriptive research is carried out to analyse the current situation of teachers in terms of the self-regulation strategies they use in reading comprehension, study habits and critical thinking. In addition to taking into consideration the results of previous studies on how to structure the app and the suggestions received from experts (experts in the design of educational apps, experts in educational technology and experts in self-regulated learning).

2.2. Participants

The reference population for this project is Spanish-speaking teachers who are continuing their training at a distance. The sample consisted of 252 participants of a distance learning master's degree in educational technology. The participants belong to 3 different nationalities: Spanish, Colombian and Ecuadorian. The distribution of participants by country is not known, due to the anonymous nature of the study, and because it is not a research variable. A similar number of participants from each country is estimated, because such a proportion exists in the master's degree.

2.3. Instruments and materials

Three different standardized questionnaires have been used to find out the teachers' weaknesses in terms of aspects of learning.

In the case of reading comprehension, the scale for the assessment of self-regulation of learning from texts in university students, ARATEX-R, by Núñez et al. (2015), was used, who validated the scale by distinguishing five dimensions: cognition management, motivation management, comprehension evaluation, planification management, and environment management.

In the case of study habits, the Self- Regulation Strategy Inventory-Self-Report questionnaire by Cleary (2006) was used, specifically a version by Hernández and Camargo (2017), who validated this same questionnaire in Spanish and adapted it to university students. The questionnaire assesses in a simple way four dimensions of how self-regulated learning influences study habits. These dimensions are inadequate regulation habits, organization of the environment, search for information and organization of the task.

For critical thinking, in relation to basic thinking, the Critical Thinking Questionnaire is used, by Santiuste et al. (2001). This questionnaire includes a substantive dimension, which measures reading, writing and listening-speaking; and a dialogic dimension, which also measures reading, writing and listening-speaking.

2.4. Procedure and data analysis

To achieve the current design of the app, the results of the questionnaires used have been analyzed to include improvements in the appropriate aspects, based on the data. Secondly, these results have been considered together with the results of the pilot experiences carried out with the first version of the app (Ortega-Ruipérez, 2022), and the recommendations of the validation by experts (Ortega-Ruipérez and Castellanos, n.p.).

A seminar on the importance of self-regulated learning was organised, convening the 650 students enrolled in the master's by mail and via the virtual classroom. At the beginning of the seminar, they were given a QR code with the questionnaire and were given 20 minutes to fill it in. The questionnaire was applied online, using Google Form. The questionnaire was answered at that time by 192 students. Afterwards, an email with the recording of the seminar was sent to all those who wanted to watch it afterwards, and they were given one week to answer the questionnaire. After one week, the number of responses was 252.

For the data analysis of the detection of needs regarding the self-regulation of reading comprehension, study habits and critical thinking, given the number of participants, it was decided to use descriptive statistics: average and standard deviation, which will allow us to know which weaknesses should be prioritized in the design of the Metadig app. To this end, the results of the items were first grouped into their corresponding dimensions, recoding the negative items where necessary to be able to analyse them together with the rest of the items.

2.5. Ethical Statement

For data collection, participants were informed about the implications of their participation in the study at the beginning of the questionnaire. A notice was included that their participation was completely voluntary, and they accepted their participation by completing the questionnaire. Furthermore, it was explained to them that their data would be used for research purposes only, the possibility of leaving the study if they wished to do so without

explanation, and that participation in the study would in no way affect their master's degree grades.

To guarantee the anonymity of the participants, no personal data was collected that was not strictly necessary for the analysis of results according to the objectives set out. This ensures compliance with the Organic Law 3/2018, of December 5, on the Protection of Personal Data and Guarantee of Digital Rights (LOPD-GDD), in line with international regulations on data protection.

All the information collected at the start of the questionnaire was recommended, and subsequently approved, by the Research Ethics Committee (REC) of the university where it was conducted. To this end, the IRB issued a certificate on the positive evaluation of its ethical suitability with the code PI014/2023.

On the other hand, the digital tool under study was used by the participants in local mode. This means that each participant downloaded the application and used it on his or her personal computer, where the data were stored without being sent or recorded on any server. This may have been a limitation for the research because it was not possible to verify how the tool was used by the participants. And, to overcome this limitation, the participants were asked directly about the frequency of use of the tool.

3. RESULTS

3.1. Weaknesses in reading comprehension, study habits, and critical thinking

Table 1 shows the descriptive statistics of the dimensions of each aspect measured. With respect to the reading comprehension questionnaire, the scoring scale is distributed on five points; while for the study habits and critical thinking questionnaires, the scoring scale is distributed on four points. As we can see in the distribution of the results, attending to the standard deviations, when the results are distributed on five points, the standard deviation is between .729 and .865; while when the results are distributed on four points, the standard deviation is between .456 and .654, confirming a normal deviation with the high number of participants.

Table 1

Results in the ARATEX-R, SRSI-SR, and Critical Thinking Questionnaire dimensions.

		Average	stand. dev.
Reading compr.	Cognition management	4,05	,729
	Motivation management	3,36	,817
	Comprehension evaluation	3,34	,865
	Planification management	3,53	,816
	Environment management	4,27	,768
Study habits	Inadequate regulation habits	3,08	,502
	Environment organization	3,36	,456
	Search for information	2,68	,654

	Organization of the task	3,18	,589
Critical thinking	Substantive dimension	3,03	,521
	Dialogic dimension	2,82	,512

To detect priorities in a similar way in the three cases (reading comprehension, study habits and critical thinking), a dimension will be considered a priority weakness to be considered for app design when the average score is below 75% of the maximum score. That is, when on the 5-point scale the average is below 3.75; and when on the 4-point scales the average is below 3.

Therefore, the results in Table 1 determine that, with respect to reading comprehension, we should especially facilitate comprehension assessment and planning management. Regarding study habits, the design should prioritize the search for information. And with respect to critical thinking, we should consider facilitating the dialogic dimension.

3.2. Application design

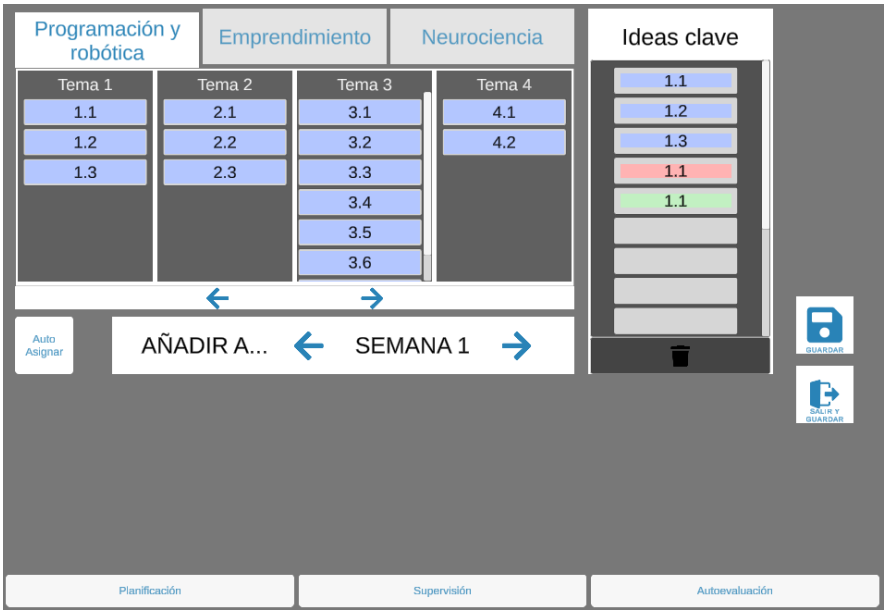
The application maintains three main screens corresponding to the three phases of self-regulated learning: planning, monitoring, and self-assessment. In addition, the design has prioritized the introduction of the experts' suggestions to simplify how objectives are introduced and how planning is performed, the introduction of activities as objectives, and the possibility of replanning. The application is available at https://bit.ly/3HoQoJN.

3.2.1. Objectives and planning

As shown in Figure 1, the objectives are sorted by subject in each subject. For this purpose, all the objectives are previously included in a .json file, which can be created by the teacher himself.

Figure 1

Screen 1: Objectives and planning



The student has two options for planning them, in a total of 15 weeks: the manual option, where the student drags those objectives or *key ideas* to the column on the right, which initially appears empty; and the automatic option if the weeks in which each objective is expected to be worked on have been included in the .json file. For the automatic option, click on the *Auto-Assign* button below the objectives.

This was one of the recommendations of the expert validation and we believe it has been successfully achieved, as the selection of objectives and their planning are now very easy for the student. In addition, activities can now be included as objectives, adding them as an additional key idea in that topic.

3.2.2. Monitoring

For monitoring, as shown in figure 2, in the key ideas that the student should work on that week, it is proposed that he/she choose a cognitive study strategy. If he/she does not know or doubts about which strategy to use, he/she has the possibility to access the information about all the strategies included (figure 3) by clicking on the button with an *i* inside a circle.

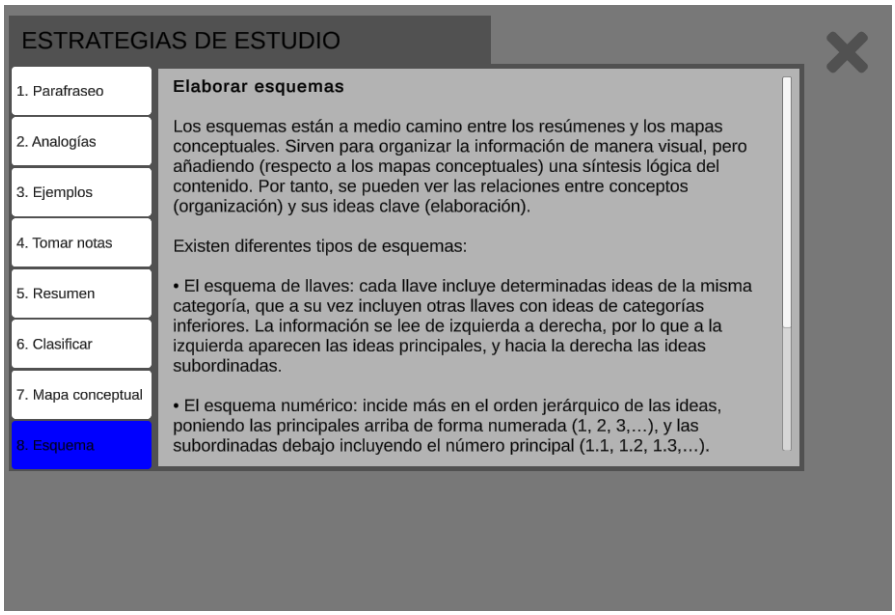
Figure 2

Screen 2: Monitoring


ESTUDIAR...
SEMANA 1
TIEMPO ESTIMADO: 01:20
Programaci...
1.1
1.2
1.3
Emprendimi...
1.1
Neurociencia
1.1
IDEA CLAVE: Por qué trabajar con robótica educativa
ESTRATEGIA DE ESTUDIO:
Ejemplos
TIEMPO ESTIMADO:
10
¿CÓMO CREES QUE HAS ESTUDIADO?
GUARDAR
SALIR Y GUARDAR
Planificación
Supervisión
Autoevaluación

Figure 3

Screen 3: Information about cognitive strategies



In addition, in the monitoring (Figure 2), the student indicates the estimated time he/she thinks it will take to work on that objective. The sum of the estimated times, for all the objectives to be worked on that week, appears at the top right of the screen, which will help you manage the planning.

Finally, on the monitoring screen (Figure 2), you are asked a reflection question about how you think you have worked on the objective, to assess your understanding after studying the objective. The answers are simplified to three icons with gestures: happy, neutral and sad, which will help you to further filter the objectives you need to work on the most before the exam.

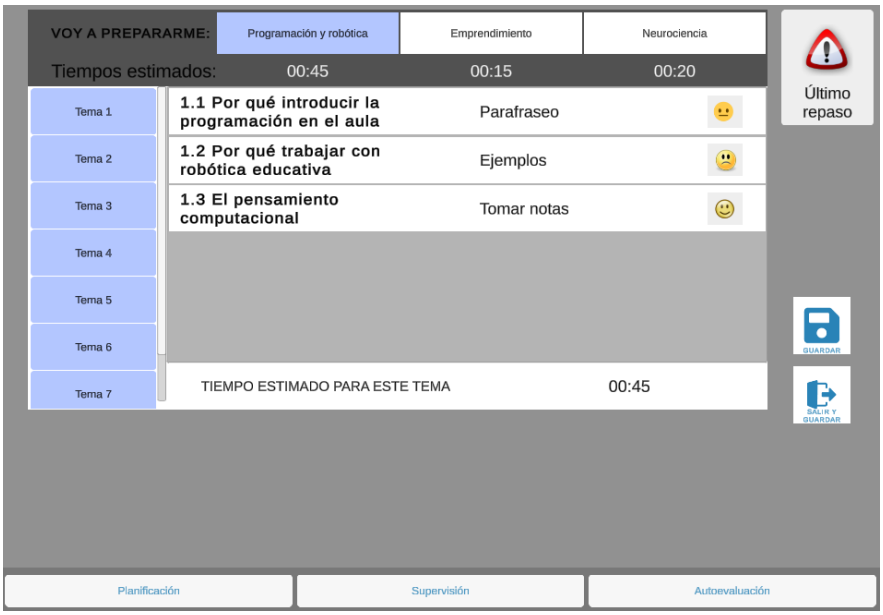
If for any problem, the student cannot prepare one of the objectives planned for that week, and wants to reschedule his study, he only must click on the planning button (bottom left) and drag the corresponding objective to the right column in the week he wants to work on it. This is another recommendation that was proposed in the expert validation, as the previous version was not flexible in this aspect.

3.2.3. Self-assessment

Finally, in the self-assessment, by selecting a subject at the top, all the corresponding topics and the results that the student had marked during the monitoring of the process (cognitive strategy used and assessment of understanding) are displayed. To do this, each objective or key idea is filtered by each subject, which appears as a menu on the left side of the screen.

Figure 4

Screen 4: Self-assessment

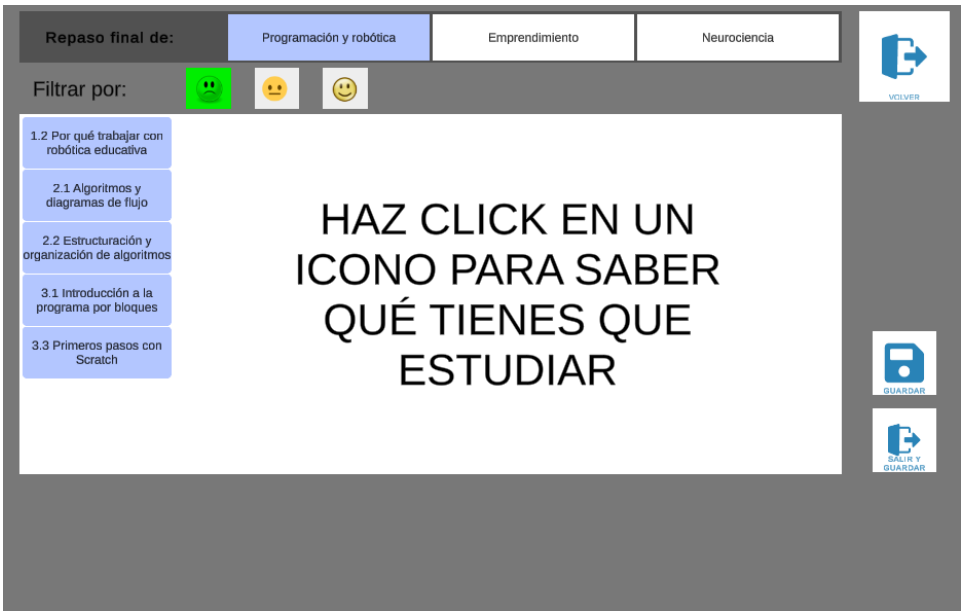


In addition, in the self-assessment (Figure 4), the student can consult the estimated time it will take to study each of the subjects, which appears just below the top menu for subject selection. This will make it easier for them to prepare for a final evaluation test.

However, another option has been included that will make it even easier for you to study for the final evaluation tests. This is a screen that allows you to filter the objectives that the student has understood the worst, which can be accessed from the button at the top right of screen 4. When accessing this last review or final review, the screen shown in figure 5 appears.

Figure 5

Screen 5: Final review



In this case, the filter is made for each of the subjects. By clicking on the top menu that filters by subject, you will be able to filter the objectives with which you are not satisfied, those with which you are moderately satisfied, and those with which you are satisfied, according to the evaluation of understanding that you made during the monitoring phase.

By being able to select only the objectives of a subject with which you were not satisfied, you will see all of them, sorted by subject. In this way, you will be able to spend more time working on these objectives, through an additional search for information until they are understood.

4. DISCUSSION AND CONCLUSIONS

The use of the first version of the application especially improved motivation management, comprehension assessment and planning in reading comprehension; and task organization in study habits (Ortega-Ruipérez, 2022).

Nevertheless, in the design of the Metadig app, specific aspects have been incorporated to facilitate strategies for the weaknesses detected:

- Comprehension assessment (Reading comprehension): this is already improved in the first version of the app, but now it also offers the possibility of evaluating comprehension through emoticons, which facilitates the classification of each objective in 3 results: I understood it well, I understood it well or I did not understand it.

- Planning management (Reading comprehension): the possibility of managing and modifying the planning has been simplified. On the one hand, it has been made possible to plan more easily according to the weekly schedule proposed by the teacher. On the other hand, time management, fundamental in planning, has been added, estimating how much time the student needs for each objective and creating a total time counter per week in the planning, and per subject in the self-evaluation.

- Search for information (Study habits): in the self-assessment, specifically in the last review, the possibility has been added to filter which objectives the student was not satisfied with or was moderately satisfied with during the supervision of the study, thus making it easier for the student to search for additional information on those objectives.

- Dialogic dimension (Critical thinking): this point is the most difficult to include in the design of the application, since it refers to the analysis and integration of divergent points of view in relation to one's own position, therefore, the construction of reasoned arguments that allow one to respond to refutations. The app does not know at which moments the person must respond to divergent positions, but some of the cognitive strategies proposed during the supervision phase have been eliminated so that the student can focus on choosing cognitive strategies related to argumentation and reasoning.

In conclusion, the Metadig app has been presented, which allows working in a simpler way on metacognitive strategies for self-regulation of learning in teachers in training. For this purpose, the design has been based on the results obtained in previous experiences and on the recommendations received in a validation study by experts. In addition, as a main contribution, some design aspects have been included that allow working, through the app, on the weaknesses detected in the study: comprehension assessment and planning management regarding self-regulation during text reading, search for information in terms of improving study habits, and, to a lesser extent, the dialogic dimension of critical thinking.

The most important limitation of the design, with respect to the study carried out here, was not being able to address the weakness of critical thinking related to the dialogic dimension in a concrete way as was done with the rest of the weaknesses detected. Future studies should rethink how to address the self-regulated use of critical thinking in a possible future version of the app.

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