THE POWER OF METACOGNITIVE STRATEGIES TO ENHANCE CRITICAL THINKING IN ONLINE LEARNING

Ana Pereles[1*] ID **, Beatriz Ortega-Ruipérez[2]** ID **, Miguel Lázaro[1]** ID

[1]Universidad Internacional de La Rioja (Spain)

[2]Universidad Rey Juan Carlos (Spain)

Corresponding author: ana.pereles@unir.net
beatriz.ortega@urjc.es, miguel.lazaro@unir.net

Abstract

The aim of this study is to verify whether the use of a digital tool, designed to promote the use of metacognitive strategies in self-regulated learning, increases the level of critical thinking during the learning process in trainee teachers in official online master's degrees. The Critical Thinking Questionnaire (CPC 2) was used to assess different dimensions of critical thinking in a sample of 225 students from an online university's master's degree in educational technology. The results showed significant improvements in all dimensions (substantive and dialogic) and associated basic skills (reading, writing, and speaking) for those who used the tool for the promotion of metacognitive strategies. Therefore, it is suggested to work on specific strategies to develop critical thinking as a basis for improving their self-regulated learning.

To cite this article:

----

1. Introduction

Nowadays, education has significantly changed as a result of the progress of information and communication technologies. In this context, online learning has gained popularity as a flexible and accessible option for professionals who wish to continue their academic training. This situation has been considered by UNESCO since 2002 and recently analysed in its publication on Education for the Sustainable Development Goals (UNESCO, 2002, 2017). However, this mode of education presents new challenges, especially with regard to the self-regulation of learning and the achievement of critical thinking (van Laer & Elen, 2017; Wong, Baars, Davis, Van Der Zee, Houben & Paas, 2019). Students have to adapt to a learning process that is different from face-to-face education (López-Pérez, Pérez-López, Rodríguez-Ariza & Argente-Linares, 2013). In this context, it is crucial that students self-regulate their learning, considering that it involves controlling and managing their own learning experience. This

includes setting goals, planning strategies, monitoring progress and evaluating the results obtained (Núñez, Cerezo, Bernardo, Rosário, Valle, Fernández et al., 2011).

Self-regulation of learning is essential in online education and is closely linked to critical thinking (Akcaoglu, Mor & Kulekci, 2023; Chang, Panjaburee, Lin, Lai & Hwang, 2022): by setting clear goals, students can plan effective strategies to achieve them; by monitoring their progress, they can identify areas for improvement and adjust their approach if necessary; and by evaluating their results, students can understand their level of achievement and determine whether they need to review or reinforce certain concepts, including seeking help (Dunn, Rakes & Rakes, 2014). Similarly, by taking control of their own learning process, students develop self-direction skills and make informed decisions about how to approach and solve educational problems (Virtanen & Tynjälä, 2019). Moreover, this capacity fosters autonomy and responsibility, two important qualities in the acquisition of knowledge (Zimmerman, 2002).

Teachers needs to focus on thinking skills, developing a culture of enquiry that promotes learning autonomy in their students (Dobber, Zwart, Tanis & van Oers, 2017). In order to achieve self-regulated learning, students employ both cognitive and metacognitive aspects. Cognitive aspects of learning refer to the strategies that students use to process, understand, and remember information (Ferreira, Olcina-Sempere & Reis-Jorge, 2019). According to recent research, cognitive strategies have been found to significantly influence students' academic performance. Specifically, critical thinking has been shown to have a significant impact on this aspect (Galikyan & Admiraal, 2019). In addition, students' autonomy has been found to be directly related to their study habits, which in turn translates into improved academic performance (Cleary, 2006). Cognitive strategies relate to the skills and techniques students use to process information and solve problems. Among them, as Manganelli, Cavicchiolo, Mallia, Biasi, Lucidi and Alivernini (2019) report, critical thinking stands out as a powerful tool that enhances text comprehension, analytical and evaluative skills, as well as the generation of original ideas and knowledgeable decision-making.

Therefore, it can be observed that critical thinking involves the ability to analyse, evaluate and synthesise information in a reflective and objective manner (Santiuste, Ayala, Barrigüete, García, González, Rossignoli et al., 2001). So much so that it is considered an essential competence in the field of education. Through critical thinking, individuals can develop a deep understanding of concepts, question pre-established ideas and make informed decisions (Baranovskaya, Shaforostova, Balykhina & Lapteva, 2018). It allows students to reflect on the information they are processing, identify assumptions and arguments, and evaluate the quality of the information (Pintrich & De Groot, 1990). It is a skill that transcends academic disciplines and is applied in a variety of contexts, including personal, academic and professional contexts.

In the case of online training, programmes aimed at developing self-regulated learning may have certain advantages over face-to-face interventions, such as the use of discussion forums (Cerezo, Bernardo, Esteban, Sánchez & Tuero, 2015; Jansen, van Leeuwen, Janssen, Conijn & Kester, 2020). However, the relationships found between metacognition, time management, effort regulation and critical thinking are lower in online interventions than in traditional settings (Broadbent, Panadero, Fuller-Tyszkiewicz, 2020). It is hence important to design virtual courses in a way that facilitates self-regulation. The Open Learner Model (OLM) (Bull & Kay, 2010) is based on the inclusion of tools to improve self-regulated learning through the presentation of questions on 4 aspects: what I know, how well I know a particular topic, what I want to know, and how I can learn it (Kay, Halin, Ottomann & Razak, 1997), aspects related to the metacognitive strategies of self-regulated learning. This model has a positive impact on students' thinking about their learning process in blended models in higher education (Hooshyar, Kori, Pedaste & Bardone, 2019), and the tools that facilitate this model help to develop self-regulated learning, including goal setting and strategy implementation, monitoring of strategies and performance (Chou & Zou, 2020).

In addition to self-regulation of learning, metacognitive strategies play a key role in the development of critical thinking. Metacognition involves learners' understanding and awareness of their own thinking processes (Schuster, Stebner, Leutner & Wirth, 2020). Applying metacognitive strategies, such as planning,

self-assessment and self-reflection, students can reflect on their learning, monitor their understanding, and regulate their own thinking, leading to an improvement in their ability to think critically and make informed decisions (Sooda, Jõgi & Kikas, 2016; Zarouk & Khaldi, 2016).

Metacognitive aspects are closely connected to students' knowledge and awareness of their own thinking and learning processes (Rivers, Nakamura & Vallance, 2022). These strategies are fundamental to students' ability to manage their study time, organise their understanding and evaluate their learning performance (Akamatsu, Nakaya & Koizumi, 2019). However, it is important to note that these strategies are only effective when students are metacognitively aware, which means, according to Rivers et al. (2022), that they have a clear insight and consciousness of their own thinking and learning procedures.

Critical thinking can thereby be seen to be a fundamental component in the learning experience, the relationship of which to self-regulated learning has not been studied as much. It seems to be central that reasoning and decision making are involved in critical thinking, as we see in many research studies on how to identify the level of critical thinking that a person has. Even with a well-founded theoretical proposal, it is very complex to measure, as situations must be set up in the tests that allow measuring critical thinking in everyday life, and not applied to a specific field. For its evaluation, in relation to basic skills, Santiuste et al. (2001) propose a Critical Thinking Questionnaire based on two dimensions of critical thinking: the substantive dimension and the dialogical dimension. Each component addresses several of the basic thinking skills proposed by Lipman (1998, cited in Santiuste et al., 2001). On the one hand, the substantive aspect includes substantive reading, substantive writing, and substantive listening-speaking. On the other hand, the dialogical component includes dialogical reading, dialogical writing, and dialogical listening-speaking.

Considering then that self-regulated learning implies that students are able to set goals, plan strategies, monitor their progress and evaluate their results (Panadero, 2017), it is understood that this skill is essential for success in online learning, where students must be responsible for their own training process. Consequently, this study will seek to assess the level of critical thinking applied to self-regulated learning during the reading and comprehension of texts in teacher training in an official online master's degree. The relationship between critical thinking and metacognitive Strategies, in the context of self-regulated Learning, will be examined. Therefore, this research aims to gain a more complete comprehension about the impact of the use of a metacognition tool on the development of critical thinking during the learning process in online education. It seeks to analyse how Metadig is influencing the way in which students develop their critical thinking skills while studying at a distance.

2. Design/Methodology/Approach

The aim of this exploratory study is to test whether the use of a digital tool, which facilitates the use of metacognitive strategies for self-regulated learning, produces significant improvements in the application of critical thinking during distance learning. To carry out the research, a quasi-experimental design was used, as participants voluntarily decided whether they wanted to use the tool or not and could not be randomly assigned to research groups.

In order to gain greater control over the independent variable (the use of the Metadig tool), both an experimental and a control group were used. In this way, it was possible to compare the improvement in both groups and to determine whether there were significant differences in terms of improvement in critical thinking due to the use of Metadig.

In addition, to ensure greater control over the independent variable, a pre-post design study was conducted, i.e., data were collected on the dependent variables (critical thinking) both before and after the intervention with the tool. This allowed us to confirm whether the observed improvement in critical thinking was significantly different after the application of the metacognitive strategies with the tool compared to its initial level.

2.1. Participants

The study was implemented in the context of the master's degree in educational technology for Teachers, which has a total enrolment population of 650 students. In this research, 252 students participated, which represents 38.7% of the population. This percentage is considered adequate to be able to generalise the results of the study. It is important to note that non-probability sampling was used, as the students decided voluntarily whether they wanted to participate in the research, which implies that it is a convenience sample.

Regarding the distribution of the participants in the research groups, it was observed that 42% of the students used the application on a regular basis, which represents 105 participants. On the other hand, 58% hardly used it beyond the first few days, involving 147 participants. These figures allowed the formation of two study groups, the first being the experimental group composed of those who used the application on a regular basis, and the second being the control group composed of those who only used it after the first few days.

2.2. Instruments and Materials

An educational training session of four hours on the use and teaching of self-regulated learning was provided as an intervention. Participants were offered the voluntary use of the digital tool Metadig (Ortega-Ruipérez & Castellanos, 2023) to self-regulate their learning in the master's degree. This tool was designed with a clear differentiation of three types of metacognitive strategies: planning, monitoring, and self-assessment.

During the first week, students planned their objectives and how to approach them. Over the next 15 weeks, corresponding to the duration of the four-month period, the application allowed them to manage and monitor their weekly progress. Finally, in the last week, the app included a self-assessment function for students to review their objectives and focus their review time on those aspects that needed more attention.

Regarding the assessment instrument, it is the standardised scale for measuring critical thinking: Critical Thinking Questionnaire (Santiuste, et al., 2001). This scale is directly related to learning through communication. Moreover, it is a self-perception survey for university students, in line with the rest of the instruments used in the research project, for which reason this questionnaire has been selected.

The instrument is composed of 30 items to assess two dimensions of critical thinking: the substantive and the dialogical. The dialogical dimension involves analysing personal thinking in relation to external perspectives, which facilitates comparison and enrichment of individuals' ideas by considering different points of view. On the other hand, the substantive dimension seeks to evaluate thinking on the basis of data and evidence, contrasting opinions and acquiring objective knowledge (Santiuste et al., 2001). The substantive domain includes reading, writing and substantive speaking, while the dialogical one includes reading, writing and dialogical speaking. Table 1 shows the items corresponding to each dimension and the basic skills covered. The questionnaire focuses on learning through communication and is used for the self-perception of university students, being consistent with other instruments of the project.

Dimension	Basic Skill	Item
Sustantive	Reading	1, 11, 13, 16, 17, 18, 19, 21, 24, 25, 28, 30
	Writting	4, 9, 10, 23, 26, 29
	Oral Expression	3, 8, 14, 27
Dialogic	Reading	2*, 7, 12, 22*,
	Writting	5, 6
	Oral Expression	15, 20

Note: Values with * indicate reversed items.

Table 1. Dimensions and basic skills associated with the Critical Thinking Questionnaire (Santiuste, et al., 2001)

The reliability analysis of the test with our sample yielded a Cronbach's alpha of 0.934. For each dimension it shows positive values: in the substantive scale (22 items) a Cronbach's alpha of .938 was obtained. With respect to the associated skills, we find that substantive reading a = .896, substantive writing a = .762 and substantive speaking a = .702. In the dialogical dimension (8 items), Cronbach's alpha is .803. If we look at each of the skills, we find that for dialogical reading a = .615, dialogical writing a = .573 and dialogical speaking a = .559. However, given the difference in scores, the substantive and dialogic dimensions will be considered in their entirety regardless of their internal abilities in order to homogenize the components and analysis.

2.3. Procedure and data analysis

During the second term of the master's programme, an intervention was organised with the students. Before the start of the term, students were contacted to explain the purpose of the research. Using various means, such as emails, notifications in the virtual classroom and phone calls from tutors, they were informed about the training available to enhance their critical thinking and learning in the master's programme.

The first part of the training took place during the first week of the term and lasted two hours. During this session, the topic of self-regulated learning was addressed and the importance of employing strategies to self-regulate their own learning process was highlighted. The main focus was on metacognitive strategies, and it was explained how they could apply them if they decided to use the Metadig tool. It is relevant to mention that the use of this tool was presented as optional and was framed within the research project.

To gather data for the study, participants were divided into two groups: the experimental group, consisting of those who used the Metadig tool, and the control group, who did not. In order to participate in the research, they were instructed to answer a questionnaire that included items from the Critical Thinking Questionnaire (Santiuste, et al., 2001), as well as other scales related to the research project. The students were offered the option of watching the session on a one-week tape-delay in case they were unable to attend live. Similarly, the questionnaire was available for one week to collect pre-test responses.

During the following 15 weeks, which coincided with the duration of the four-month period, the students used the tool autonomously, organising their learning process as they saw fit. They were reminded to use the tool twice during the term, in weeks five and ten. Before the exams, they were also reminded how to use the self-assessment menu of the tool to improve their study.

The second session of the training, also lasting two hours, was held at the end of the term. This time, the topic was how to teach their own students' strategies for self-regulating their learning. The first half hour of the session was spent reflecting together on how the tool had helped them and whether they felt that these strategies could be useful for their students. At the end of the seminar, they were thanked for their participation and asked again to fill in the questionnaire to obtain the answers for the post-test. Students who could not attend live had the opportunity to watch the recorded session and answer the questionnaire during the following week.

Regarding data analysis, the reliability of the test was first assessed in the study sample by means of Cronbach's alpha analysis, both for all items in general and for the items of each dimension. In this way, it was possible to affirm that the measurement instrument used is suitable for assessing critical thinking in this specific sample.

Two variables were created for each dimension, one with the pretest items and the other with the post-test items. Considering that the instrument is standardised and has been validated in previous studies (see Santiuste, et al., 2001), the variables were calculated from the average value of the items corresponding to each dimension of the study. It is important to mention that items 2 and 22, which belong to the dialogical dimension, had to be recoded, as they were originally posed as inverse items.

In the third step of the analysis, we checked whether the sample distribution corresponded to a normal distribution for each dimension. For those dimensions that followed a normal distribution, a Generalized Linear

Model with Gaussian distribution was applied. On the other hand, for the dimensions with a non-symmetric distribution, a Generalised Linear Model was also used, but adjusting with the Gamma distribution.

For both cases, the impact of belonging to one group or the other was assessed, i.e., whether participants used the Metadig tool to employ metacognitive self-regulation strategies. This variable was considered as the factor in the test. The aim was to measure the impact that the group had on each dimension of study, using the post-test variable of each dimension as the dependent variable to assess its impact after the intervention. In addition, to know the real impact, independent of the pretest effect, the pretest variable of the dimension was included as a covariate.

Statistical analysis was performed using Jamovi software, version 2.3.26. The results were presented using tables provided by Jamovi, and attention was paid to several important statistics. These tools and metrics provided a coherent and logical understanding of the data collected, allowing meaningful conclusions to be drawn about the relationship between the use of the tools and the use of the tools.

The correlation coefficient ($R2$) was one of the metrics used to determine the amount of variability explained by the model. This allowed us to compare different dimensions and determine which of them explained a greater proportion of the total variance.

To interpret the regression coefficients of the model, the value of the intercept estimator was analyzed. This value represents the average on the post-test dimension once the initial level was controlled for by the pretest. In addition, if the regression coefficient was significant ($p < 0.05$), the effect, i.e., the average score that a person in the group not using the Metadig tool would have, could be known.

The effect variable (groups variable) was assessed to verify whether the change between the groups was significant after controlling for the initial variable (pretest). For this, the Bonferroni correction was used, a more robust adjustment due to the sample size. The estimator of this variable allowed predicting how much the group that used Metadig improved compared to the mean score of a person in the group that did not use Metadig. In addition, the Marginal Means Plot was used to visually verify the influence of the group on the dimension, independent of the pretest effect.

In this sense, the impact of the Metadig tool on the critical thinking of the participants was evaluated through these analyses, considering the different study dimensions, and controlling the effect of the pretest on the results.

2.3.1. Substantive Dimension

Using the Shapiro-Wilk test it is observed that this domain does not follow a normal distribution ($p = 0.010$), so the Generalized Linear Models test is used with the Gamma distribution for non-symmetric distributions. In this case, the percentage of the total variance of the substantive dimension explained by the regression is 23.2%, and the predictors (group and pretest) are statistically significant ($p < 0.01$). The $R2$ value will be used later to test which aspect explains a larger proportion of the total variance.

Names	Effect	Estimate	SE	95% Confidence Interval		z	p
				Lower	Upper		
(Intercept)	(Intercept)	3.165	0.0381	3.0919	3.241	83.08	< .001
UsoApp1	1 - 0	0.194	0.0611	0.0738	0.314	3.16	0.002
SustantivaPre	SustantivaPre	0.155	0.0665	0.0260	0.281	2.33	0.021

Table 2. Parameter Estimates for Substantive Dimension

In the parameter estimation (Table 2) it can be noticed that the mean estimated value for someone who belongs to the group that does not regularly use metacognitive strategies is 3.17 points. A person who regularly uses these strategies could have 0.19 points more, i.e., 3.36 points out of 4. Looking at the

Bonferroni corrected test (Table 3), it is confirmed that the difference between groups is significant. This difference can be seen graphically in Figure 1.

Comparison		Difference	SE	z	Pbonferroni
UsoApp	UsoApp				
0	-	1	-0.194	0.0611	-3.16	0.002

Table 3. Post Hoc Comparisons – UsoAPP for Substantive Dimension
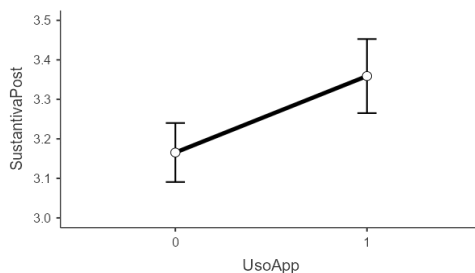
Figure 1. Plots - estimated marginal means by group for Substantive Dimension

2.3.2. Dialogical Dimension

The Shapiro-Wilk test is analyzed, and it is observed that the distribution of the dialogical dimension does not follow a normal distribution ($p = 0.035$). Therefore, the Generalized Linear Models with the Gamma distribution, suitable for non-symmetric distributions, is applied. In this case, the regression model explains 37.1% of the total variance of the domain. The predictors used, i.e., the group to which the participants belonged (use or not of metacognitive strategies) and the pretest values, were statistically significant ($p < 0.01$). The $R2$ value obtained will be used later to determine which dimension has a greater impact on the total variance.

Names	Effect	Estimate	SE	95% Confidence Interval		z	p
				Lower	Upper		
(Intercept)	(Intercept)	2.910	0.0337	2.845	2.977	86.37	< .001
UsoApp1	1 - 0	0.274	0.0550	0.166	0.384	4.99	< .001
DialógicaPre	DialógicaPre	0.286	0.0606	0.167	0.404	4.71	< .001

Table 4. Parameter Estimates for Dialogic Dimension

In Table 4, the estimated parameters reveal that the mean value for an individual who regularly does not use metacognitive strategies is 2.91 points. In contrast, those who do use these strategies regularly could have an average of 0.27 points more, reaching a score of 3.18 points out of 4. Likewise, the Bonferroni corrected test (Table 5) confirmed that the difference between the two groups is significant. This is graphically presented in Figure 2, where the influence of the group on the dimension studied can be clearly observed.

Comparison		Difference	SE	z	Pbonferroni
UsoApp	UsoApp				
0	-	1	-0.274	0.0550	-4.99	< .001

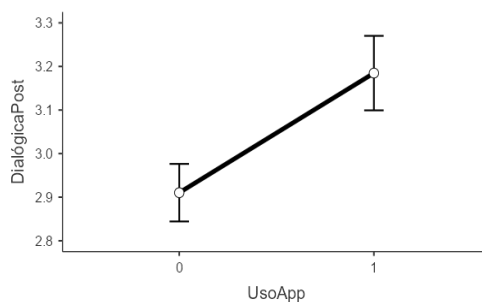Table 5. Post Hoc Comparisons – UsoAPP for Dialogic Dimension

Figure 2. Plots - estimated marginal means by group for Dialogic Dimension

3. Results

Once the differences between the groups have been verified as statistically significant in all dimensions, Table 6 provides important information in two aspects. First, it shows the percentage of variance explained using Metadig in each of the dimensions. Second, it presents the difference in mean scores between those who regularly use metacognitive strategies with the help of Metadig and those who do not. Although all differences are significant, this information will help us to determine in which dimensions the use of Metadig may be most beneficial in improving critical thinking in both the substantive and dialogical dimensions.

Dimension	R2	Mean G-0	Mean G-1	Difference
Substantive	0.232	3.17	3.36	0.194
Dialogic	0.371	2.92	3.18	0.274

Table 6. Results for dimensions

According to the effects in Table 7, the regular use of metacognitive strategies through the Metadig tool explains 37.1% of the improvement in critical thinking skills for the dialogical dimension, followed by 23.2% in the substantive dimension. Although these results are admittedly moderate, considering that the pretest effect was controlled for, and the groups were assumed to be equal, significant differences were found between the groups in all cases.

	N	R2	Pbonferroni	Mean G0	Mean G1
Substantive					
Reading	252	0.078	< .001	3.07	3.27
Writing	252	0.059	0.003	3.17	3.34
Oral expression	252	0.108	< .001	3.05	3.27
Dialogic					
Reading	252	0.122	< .001	2.82	3.13
Writing	252	0.141	< .001	3.04	3.32
Oral expression	252	0.100	0.003	2.94	3.17

Table 7. Results in the different dimensions of critical thinking applied
to self-regulation of learning while reading texts

Analyzing the mean average differences between the groups in each dimension, controlling for the effect of the pretest, we observe that the biggest difference is also found in the dialogical dimension compared to the substantive dimension. All these results show a gap of around 0.3 points over the four points at which the measurements were taken, although the intergroup differences are statistically significant at all the levels considered.

Once detailed information on the dimensions has been presented, it is important to look at the associated basic skills, and to examine their differences, for further reflection and discussion. Accordingly, Table 7 provides statistical information, as well as the number of subjects participating in the research. The analysis includes the correlation coefficient ($R2$) which is used to measure the amount of variability that the model explains. This is useful for comparing different dimensions and determining which one contributes most to the total variance. In addition, the Bonferroni correction is applied, and a marginal means plot is used to visualise the influence of the group on the dimension, independent of the pretest effect.

Using a 4-point Likert scale, a score of 3 out of 4 is considered a sufficient level of critical thinking during self-regulated text reading. This average score can be seen in 75% of those who do not use the application, compared to 100% who exceed this average among those who do use it. Similarly, statistically significant differences are observed in all the basic skills covered by both dimensions. For the substantive dimension, there is a variance of between 6% and 10% between those who do and do not use the tool. In the reading component, the mean of those who have not used Metadig (3.07) indicates that a sufficient level is generally achieved, rising by 0.20 points for those who do use the tool. This difference in averages is practically the same in writing and speaking, being slightly higher in the latter (0.22 points improvement for those who do use the application).

Meanwhile, in the dialogical dimension, a greater variability is observed than in the substantive domain. In this case, between 10% and 14.1% improvement in critical thinking when using the tool. The average in reading (2.82) and speaking (2.94) by those who did not use Metadig is not sufficient. Those who did use the tool, however, managed to score 3.1 points, with a difference of around 0.30 points in each skill. The same happens in oral expression within the substantive dimension, with a difference in means to be considered and where the greatest intergroup variability is observed.

Consequently, the findings reveal an interesting improvement in critical thinking in the substantive and dialogical dimensions during the reading of texts in those who have used the Metadig tool. Similarly, a level of critical thinking can be observed with averages higher than 3 points (out of 4) in all the factors studied for the experimental group. Therefore, these results confirm the need to implement specific strategies for the development of critical thinking, as well as the usefulness of conducting courses and using tools such as Metadig, as it is essential to improve students' self-regulated learning.

4. Conclusions

The main objective of this study was to test whether the use of a digital tool such as Metadig, which enables the development of metacognitive strategies for self-regulated learning, produces significant improvements in the application of critical thinking. This would be in line with recent research such as that of Akcaoglu et al. (2023), who emphasise that using metacognitive strategies linked to self-regulated learning improves critical thinking. In the proposed intervention, the training sessions highlighted the benefits of developing cognitive and metacognitive strategies linked to self-regulated learning in face-to-face and online teaching (Chang et al., 2022). In turn and following authors such as Galikyan and Admiraal (2019) and Manganelli et al. (2019) these benefits will impact on the development of critical thinking.

The contributions of Santiuste et al. (2001), who proposed a Critical Thinking Questionnaire in relation to basic thinking, approaching it from the substantive and dialogical dimensions, have been considered in this case. The first dimension linked to critical thinking studied in this research is the substantive dimension. Mastering this involves understanding, creating, and communicating information in a coherent, clear, and meaningful way (Bunci, 2019). The results of the research show that the group that used the Metadig tool to develop metacognitive strategies showed improvements compared to the group that did not use the tool. This improvement, which can also be observed in the different aspects that make up the substantive dimension, helps to develop critical thinking as stated by Sooda et al. (2016).

The results reveal that within the substantive dimension, the group that has used Metadig improves in reading, writing and oral expression compared to the group that has not used the tool. These significant

increases lead to a greater development of critical thinking, which according to Zarouk and Khaldi (2016) may be because the application of metacognitive strategies makes students reflect on their own learning. This leads to an improvement in the ability to think critically.

The substantive dimension of critical thinking enhancement can be said to be closely linked to the development of self-regulatory learning strategies and skills (Rivers et al., 2022). The development of these skills that occurs when using tools such as Metadig helps to foster critical thinking in its substantive dimension and provides the basis for students to be able to self-regulate and improve their learning process in a reflective manner (Puerta-Vásquez & Suárez-Molina, 2022).

On the other hand, the influence of the use of metacognitive strategies through the Metadig tool on the dialogical dimension of critical thinking was also studied. The results show that, in general, there has been a significant improvement in this dimension in the members of the group that used the Metadig tool compared to those who did not use it. The results obtained in this domain allow us to affirm, following Santana, Cedeño, Atoche, Torres, Preciado and Quito (2022), that the use of metacognitive strategies improves the ability to reason and make decisions when interacting with one's own and other people's ideas, which in turn influences the development of critical thinking.

Within the dialogical dimension, as in the substantive dimension, the changes produced in the three basic skills were measured: reading, writing and oral expression, as was the case in the research carried out by Santiuste, et al. (2001). Here, the teachers who used Metadig showed improvements in the three basic skills compared to the group of teachers who did not use the tool. It should be noted, in turn, that the improvements produced in these skills linked to the dialogic dimension are greater than those obtained by the same group in the substantive dimension. This allows us to conclude, following Vicente-Gutierrez (2021), that although the use of metacognitive strategies improves both dimensions of critical thinking, the impact on each of them is different.

The study's general conclusion, with a pretest and post-test design, is that the use of digital tools that promote the use of metacognitive strategies such as Metadig, develop critical thinking, both in the substantive and dialogical dimensions. In turn, the development that occurs in critical thinking, thanks to the development of self-regulation learning skills, would help, along the lines of research such as that of Dunn et al. (2014), to plan effective strategies to achieve goals, to identify points for improvement and to be more effective in seeking help, given that they improve communication.

The need to integrate into the teaching process tools that promote cognitive strategies linked to the self-regulation of learning, both for teachers and students, must be emphasised. This is why it is considered that this type of research contributes to the scientific field of metacognition to understand the relationship between the use of metacognitive strategies and learning components as important as critical thinking. Although attention is being paid to this topic in recent years, it is a relatively new field that requires much more empirical support. In this way, we will be able to focus on improving the design of the tool in the future to enhance these aspects.

Declaration of Conflicting Interests

Funding

References

Akamatsu, D., Nakaya, M., & Koizumi, R. (2019). Effects of metacognitive strategies on the self-regulated learning process: *The mediating effects of self-efficacy. Behavioral Sciences,* 9(12), 128. https://doi.org/10.3390/bs9120128

Akcaoglu, M.O., Mor, E., & Kulekci, E. (2023). The mediating role of metacognitive awareness in the relationship between critical thinking and self-regulation. *Thinking skills and creativity,* 47(101187). https://doi.org/10.1016/j.tsc.2022.101187

Baranovskaya, T., Shaforostova, V., Balykhina, T., & Lapteva, E. (2018). Critical thinking in self-regulated learning. In Luis Gómez Chova, A. López Martínez, I. Candel Torres. *Conference Proceedings. Edulearn 18. 10th International Conference on Education and New Learning Technology*, pag. 7373-7381.https://doi.org/10.21125/edulearn.2018.2492

Broadbent, J, Panadero, E., & Fuller-Tyszkiewicz, M. (2020). Effects of mobile-app learning diaries vs online training on specific self-regulated learning components. *Educational Technology Research and Development*, 68, 2351-2372.

Bull, S., & Kay, J. (2010). Open Learner Models. In: Nkambou R., Bourdeau J., Mizoguchi R. (Eds.), *Advances in Intelligent Tutoring Systems. Studies in Computational Intelligence* (308). Springer. https://doi.org/10.1007/978-3-642-14363-2_15

Bunci, M.G. (2019). Las dimensiones sustantivas y dialógicas del pensamiento crítico en estudiantes de bachillerato y universitarios. *Cátedra*, 2(1), 60-75. https://doi.org/10.29166/catedra.v2i1.1215

Cerezo, R., Bernardo, A., Esteban, M., Sánchez, M., & Tuero, E. (2015). Programas para la promoción de la autorregulación en educación superior: un estudio de la satisfacción diferencial entre metodología presencial y virtual. *European Journal of Education and Psychology,* 8(1), 30-36. https://doi.org/10.30552/ejep.v8i1.144

Chang, C.Y., Panjaburee, P., Lin, H.C., Lai, C.L., & Hwang, G.H. (2022). Effects of online strategies on students' learning performance, self-efficacy, self-regulation and critical thinking in university online courses. *Educational Technology Research and Development,* 70(1), 185-204. https://doi.org/10.1007/s11423-021-10071-y

Chou, C.Y., & Zou, N.B. (2020). An analysis of internal and external feedback in self-regulated learning activities mediated by self-regulated learning tools and open learner models. *International Journal of Educational Technology in Higher Education,* 17(1), 1-27. https://doi.org/10.1186/s41239-020-00233-y

Cleary, T.J. (2006). The development and validation of the self-regulation strategy inventory–self-report. *Journal of school psychology,* 44(4), 307-322. https://doi.org/10.1016/j.jsp.2006.05.002

Dobber, M., Zwart, R., Tanis, M., & van Oers, B. (2017). Literature review: The role of the teacher in inquiry-based education. *Educational Research Review*, 22, 194-214. https://doi.org/10.1016/j.edurev.2017.09.002

Dunn, K.E., Rakes, G.C., & Rakes, T.A. (2014). Influence of academic self-regulation, critical thinking, and age on online graduate students' academic help-seeking. *Distance Education,* 35(1), 75-89. https://doi.org/10.1080/01587919.2014.891426

Ferreira, M., Olcina-Sempere, G., & Reis-Jorge, J. (2019). Teachers as Cognitive Mediators and Promotors of Meaningful Learning. *Revista de Educación,* 43(2), 603-614. https://doi.org/10.15517/revedu.v43i2.37269

Galikyan, I., & Admiraal, W. (2019). Students' engagement in asynchronous online discussion: The relationship between cognitive presence, learner prominence, and academic performance. *The Internet and Higher Education*, 43. https://doi.org/10.1016/j.iheduc.2019.100692

Hooshyar, D., Kori, K., Pedaste, M., & Bardone, E. (2019). The potential of open learner models to promote active thinking by enhancing self-regulated learning in online higher education learning environments. *British Journal of Educational Technology,* 50(5), 2365-2386. https://doi.org/10.1111/bjet.12826

Jansen, R.S., van Leeuwen, A., Janssen, J., Conijn, R., & Kester, L. (2020). Supporting learners' self-regulated learning in Massive Open Online Courses. *Computers & Education,* 146(103771). https://doi.org/10.1016/j.compedu.2019.103771

Kay, J., Halin, Z., Ottomann, T., & Razak, Z. (1997). Learner know thyself: Student models to give learner control and responsibility. In *Proceedings of International Conference on Computers in Education* (17-24).

López-Pérez, M.V., Pérez-López, M.C., Rodríguez-Ariza, L., & Argente-Linares, E. (2013). The influence of the use of technology on student outcomes in a blended learning context. *Educational Technology Research and Development*, 61, 625-638. https://doi.org/10.1007/s11423-013-9303-8

Manganelli, S., Cavicchiolo, E., Mallia, L., Biasi, V., Lucidi, F., & Alivernini, F. (2019). The interplay between self-determined motivation, self-regulated cognitive strategies, and prior achievement in predicting academic performance. *Educational Psychology, An International Journal of Experimental Educational Psychology,* 39(4), 470-488. https://doi.org/10.1080/01443410.2019.1572104

Núñez, J.C., Cerezo, R., Bernardo, A.B., Rosário, P., Valle, A., Fernández, M.E. et al. (2011). Implementation of training programs in self-regulated learning strategies in Moodle format: Results of an experience in higher education. *Psicothema,* 23(2), 274-281.

Ortega-Ruipérez, B., & Castellanos, A. (2023). Guidelines for instructional design of courses for the development of self-regulated learning for teachers. *South African Journal of Education,* 43(3). https://doi.org/10.15700/saje.v43n3a2202

Panadero, E. (2017). A review of self-regulated learning: Six models and four directions for research. *Frontiers in psychology,* 8(422). https://doi.org/10.3389/fpsyg.2017.00422

Pintrich, P. R., & De Groot, E. (1990). Motivational and self-regulated learning components of classroom academia performance. *Journal of Educational Psychology*, 82, 33-40.

Puerta-Vásquez, S.M., & Suárez-Molina, V.J. (2022). Estrategia didáctica mediada por el aprendizaje autorregulado para el desarrollo del pensamiento crítico en educación artística. *INNOVA Research Journal,* 7(1). 38-58.

Rivers, D.J., Nakamura, M., & Vallance, M. (2022). Online self-regulated learning and achievement in the era of change. *Journal of Educational Computing Research,* 60(1), 104-131. https://doi.org/10.1177/07356331211025108

Santana, L. M. Q., Cedeño, B. J. B., Atoche, C. B., Torres, C. V. G., Preciado, M. P. U., & Quito, C. R. M. (2022). Estrategias metacognitivas y pensamiento crítico en docentes. *Ciencia Latina Revista Científica Multidisciplinar,* 6(1), 649-675. https://doi.org/10.37811/cl_rcm.v6i1.1529

Santiuste, V., Ayala, C., Barrigüete, C., García, E., González, J., Rossignoli, J. et al. (2001). *El pensamiento crítico en la práctica educativa*. Madrid: Fugaz Ediciones.

Schuster, C., Stebner, F., Leutner, D., & Wirth, J. (2020). Transfer of metacognitive skills in self-regulated learning: an experimental training study. *Metacognition and Learning,* 15(3), 455-477. https://doi.org/10.1007/s11409-020-09237-5

Soodla, P., Jõgi, A.L., & Kikas, E. (2016). Relationships between teachers' metacognitive knowledge and students' metacognitive knowledge and reading achievement. *European Journal of Psychology of Education,* 32(2), 201-218. https://doi.org/10.1007/s10212-016-0293-x

UNESCO (2002). *Aprendizaje abierto y a distancia: consideraciones sobre tendencias, políticas y estrategias*. Available at: https://unesdoc.unesco.org/ark:/48223/pf0000128463_spa

UNESCO (2017). *Educación para los Objetivos de Desarrollo Sostenible: objetivos de aprendizaje*. Available at: https://unesdoc.unesco.org/ark:/48223/pf0000252423

van Laer, S., & Elen, J. (2017). In search of attributes that support self-regulation in blended learning environments. *Education and Information Technologies,* 22(4), 1395-1454. https://doi.org/10.1007/s10639-016-9505-x

Vicente-Gutiérrez, G.E. (2021). *Implementación de estrategias metacognitivas en el desarrollo del pensamiento crítico en estudiantes de educación de una Universidad Pública de Lima*. Respositorio de la Universidad César Vallejo. [Tesis Doctoral] https://hdl.handle.net/20.500.12692/68762

Virtanen, A., & Tynjälä, P. (2019). Factors explaining the learning of generic skills: a study of university students' experiences. *Teaching in Higher Education,* 24(7), 880-894. https://doi.org/10.1080/13562517.2018.1515195

Wong, J., Baars, M., Davis, D., Van Der Zee, T., Houben, G.J., & Paas, F. (2019). Supporting self-regulated learning in online learning environments and MOOCs: A systematic review. *International Journal of Human–Computer Interaction,* 35(4-5), 356-373. https://doi.org/10.1080/10447318.2018.1543084

Zarouk, M.Y., & Khaldi, M. (2016). Metacognitive learning management system supporting self-regulated learning. In *2016 4th IEEE International Colloquium on Information Science and Technology (CIST)* (929-934). IEEE. https://doi.org/10.1109/CIST.2016.7805021

Zimmerman, B.J. (2002). Becoming a self-regulated learner: an overview. *Theory Into Practice,* 41(2), 64-70. https://doi.org/10.1207/s15430421tip4102_2