



Self-Regulated Learning Interventions for Pre-service Teachers: a Systematic Review

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Abstract

Self-regulated learning (SRL) is a key competence for pre-service teachers to develop, both for their own activities as learners and for their future activities as teachers. Therefore, it is crucial to understand how pre-service teachers can be supported in acquiring SRL competence in their initial training. To reach this aim, we conducted a systematic review of SRL interventions for pre-service teachers. Sixty-six intervention studies fulfilled the inclusion criteria. We explored three aspects of those SRL interventions, and how they moderate the interventions' effectiveness: (1) the theoretical and practical underpinnings of SRL, (2) whether the intervention aimed to promote SRL learning and/or teaching of SRL, and (3) the intervention's pedagogical characteristics and content related to the SRL professional competences. We found that the most effective SRL interventions (1) focused the training on one or two SRL areas (especially cognition and metacognition); (2) when targeted both, SRL learning and teaching of SRL, pre-service teachers' SRL skills improved as well as their pedagogical skills; and (3) addressed direct and implicit SRL instruction, inside which self-assessment of learning and teaching practices appear as an effective pedagogical method. We derive implications from our findings for designing effective SRL interventions for prospective teachers.

Keywords SRL · Training · Pre-service teachers · Effectiveness · Systematic review

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Self-regulated learning (SRL) is a pivotal skill that improves academic performance, enhances learners' autonomy, and supports their holistic development (Dignath & Veenman, 2020; Winne & Marzouk, 2019). Importantly, SRL is composed of different areas (e.g., regulation of cognition, motivation, emotion), and a myriad of factors influence its development. This makes the promotion of SRL a compulsory activity at schools to ensure that all learners have the opportunity to become self-regulated learners (Panadero, 2017). Therefore, it is key that (pre-service) teachers integrate SRL as part of their own learning and teaching (Dignath & Veenman, 2020).

To this end, it is crucial to understand if and how teachers acquire the competence to promote SRL throughout their careers. Notably, in order to develop this competence as early as possible, teachers should learn about SRL and SRL support as soon as they start their training. Thus, research needs to investigate pre-service teachers' SRL training to enlarge understanding of how to support them in becoming self-regulated learners and teachers (Kramarski & Michalsky, 2010). For this reason, our aim is to examine the characteristics and effects of SRL interventions designed for pre-service teachers.

Self-Regulated Learning (SRL)

“Self-regulated learning refers to self-generated thoughts, feelings, and actions that are planned and cyclically adapted to the attainment of personal goals” (Zimmerman, 2000, p.14). SRL represents a dynamic process influenced by various factors within the students' internal characteristics (e.g., cognitive, motivational) and external environments. With the aim of clarifying and understanding these complex interactions, researchers have created different models which explain SRL and how it works (Panadero, 2017).

These models share that SRL is composed of different phases, and most models include a preparatory phase, a performance phase, and an appraisal phase (Panadero, 2017). Moreover, the models describe cognitive, metacognitive, motivational, and emotional aspects of SRL. Accordingly, Zimmerman's definition of SRL encompasses all of these models, even if each individual model has its own approach. However, there are differences on the emphasis given to each of these aspects. For example, some models (e.g., Zimmerman, Pintrich) present a balanced description of the areas of SRL, while others (e.g., Boekaerts) are more concentrated in one of them. Therefore, depending on the area that needs intervention, some models might be more suitable than others (Panadero, 2017). For that reason, in our research question one, we will explore the occurrence of the models among the SRL interventions.

Self-Regulated Learning Areas and Strategies

A self-regulated learner applies multiple strategies in the areas of cognition, metacognition, motivation, emotion, behavior, and context that serve to regulate one's learning. In fact, an expert self-regulated learner is able to control these areas by

planning, developing, reflecting upon, and adapting strategies. These strategies are concrete tactics students put into action when regulating their learning.

In order to gain a comprehensive understanding of pre-service teachers' learning about these strategies, we adopted Pintrich's (2000) model as the basis because of its accessible classification of the areas and strategies that learners use to regulate their learning process. This includes metacognition, cognition, motivation, emotion, behavior, and context, making it easier to operationalize them when creating the coding. Unlike Pintrich, however, we classified motivation and emotion into two different areas, as they involve two different processes for our understanding (Boekaerts & Corno, 2005).

Table 1 presents the SRL areas and the strategies within each area. However, we understand that the boundaries between areas can sometimes be blurred, as a strategy may have components from different areas. For example, ease of learning, which Pintrich classifies as a motivational strategy, also contains a strong metacognitive component. For theoretical clarity, we have adapted some of the terms used in Pintrich's original model to make the naming of strategies more precise (e.g., cognitive attributions changed to adaptive attributions). Furthermore, we have reclassified the motivational strategies of effort, persistence, and help seeking as behavioral as they are closely related to behavioral control and directly affect students' attempts to control their actions (Pintrich, 2000).

In summary, SRL encompasses different areas with different strategies and impacts. Therefore, it is important to investigate which area is most significant when teachers learn about SRL, and whether SRL interventions for pre-service teachers have a balanced representation of these areas. For that reason, in our research question one, we will investigate which areas and specific strategies SRL interventions are most likely to promote.

Teaching Self-Regulated Learning: Teachers' Professional Development and SRL Dual Role

Given the complexity of mastering self-regulated learning (SRL) without proper training, the role of the teacher becomes crucial. Research has stated that when it comes to teaching of SRL, teachers are placed in a dual role. First, teachers need to apply the SRL principles to their own learning. This means that they need to plan, monitor their performance, self-reflect, etc. In other words, teachers need to be self-regulated professionals. Second, teachers need to be promoters of their students' SRL (Karlen et al., 2020; Kramarski & Kohen, 2017; Kramarski & Revach, 2009). Recently, Kramarski and Heaysman (2021) have shown that there is a third role that teachers need to address, meaning self-regulation for their teaching actions (pedagogical knowledge and practice of SRL teaching). This model gives a comprehensive insight of teachers' skills in classroom context.

However, as Kramarski and Kohen (2015) stated, (pre-service) teachers need to address their SRL as learners (SRL professionals) so that they can become master promoters of SRL. This is, teachers may need to be trained on their own use of SRL before they are properly able to promote SRL to students, and so master the pedagogical

Table 1 SRL areas and strategies' examples

Area	Strategy	Example
Cognition and metacognition	Goal setting	<i>I will make a list of to do things</i>
	Prior knowledge activation	<i>What do I know about the task and what do I need to learn?</i>
	Selection and adaptation of specific strategies	<i>Should I memorize or make a diagram?</i>
	Metacognitive knowledge and awareness	<i>Has the strategy I have used helped me to learn or do I have to change it?</i>
	Metacognitive judgements /Monitoring of cognition	<i>I do not understand what I am reading, maybe I have to find another way to work on it</i>
Motivation	Adaptive attributions	<i>This poor result is due to lack of time to study, I must plan better</i>
	Goal orientation	<i>I will focus on the to-do list so I can learn what I need to learn</i>
	Self-efficacy	<i>I feel able to complete this task</i>
	Perceptions of task difficulty	<i>This task is easy, I can do it</i>
	Task value	<i>I think this task will for sure help me to be a better professional</i>
Emotion	Interest	<i>This task is quite boring</i>
	Motivational control	<i>I am feeling really unmotivated, so for each part I study I will eat a piece of chocolate</i>
	Affective reactions towards a task or situation	<i>I feel anxious because the exam did not go well</i>
	Emotional control	<i>I need to control this anxiety, let's have a break and take some deep breaths</i>
	Self-observation of behavior	<i>I will use a writing registration of my study time</i>
Behavior	Time management	<i>My time registration sheet is helping me with the preparation of the exam</i>
	Effort	<i>Today I will spend two hours studying for the exam, and then I will rest</i>
	Persistence	<i>I cannot give up, I know I can do it</i>
	Help seeking	<i>I will ask my professor for help</i>
	Change task	<i>I am not being productive at writing the essay, I'll rather start studying for the exam so I can make progress</i>
Context	Change environmental conditions	<i>I cannot concentrate in this room, I will change locations so that I can be more productive</i>

practice of SRL teaching. For this reason, in this review, we will put emphasis on the dual role (pre-service teachers as SRL professionals and SRL promoters).

Teachers as Self-Regulated Professionals

As self-regulated professionals, teachers need to reflect upon their practice, beliefs, and thoughts in order to regulate their teaching actions (Kramarski & Kohen, 2015). This reflection needs to be based on an analytical observation of themselves which implies a high level of metacognitive knowledge (Dignath, 2021). Additionally, teachers need SRL content knowledge, which refers to understanding what SRL is and how it works (Karlen et al., 2020). This knowledge will come from the training that teachers receive (Dignath & Büttner, 2018), but also from teachers' experiences with their own learning (Gordon et al., 2007). Thus, teachers need metacognitive knowledge about SRL in order to be able to critically reflect on their thoughts and beliefs about SRL.

Teachers as Promoters of SRL

As promoters of SRL, teachers need pedagogical content knowledge about how to teach and apply SRL with their students in specific contexts and situations (Karlen et al., 2020). The mastery of SRL pedagogical content knowledge and its usage will allow teachers to give meaning to the strategies and pedagogical practices addressed in their lessons (Dignath, 2021; Endedijk, 2014; Virtanen et al., 2017).

In addition, teachers have to be aware of how their students' use SRL strategies, so that they can direct teaching to students' needs (Michalsky, 2020; Paris & Winograd, 2003). For this reason, teachers have to assess their students' SRL (Karlen et al., 2020). Unfortunately, there is not a lot of research on how they do so. The few studies on this indicate that many teachers do not have conceptions of SRL that are consistent with SRL theory and that misconceptions about SRL affect their ideas about how to assess it and which cues to use for this assessment (Dignath & Sprenger, 2020).

Teachers' dual role in the context of SRL has been investigated already for some time (Kramarski and Heaysman (2021), Kramarski and Michalsky (2009), Dembo (2001), Moos and Ringdal (2012), Randi (2004)). It is therefore time to examine how pre-service teachers can be optimally supported in their development into self-regulated learners and facilitators of SRL. To this end, our research question two examines whether these SRL interventions address skills related to both roles.

Self-Regulated Learning Interventions for Teachers: Pedagogical Characteristics and Content

Teachers, just like students, may develop the necessary SRL competencies more effectively with training. Therefore, when designing training, particular characteristics have to be considered. Pre-service teachers can conceive themselves as learners due to their

lack of teaching experience, while in-service teachers should have sound knowledge and beliefs in the field of education and may find it more difficult to put themselves in the role of learners. On the other hand, both, pre-service and in-service teachers experience large gaps in knowledge and practice in promoting SRL (Dignath & Büttner, 2013). This implies that the training required for each group of teachers will be different, and so it is important to define how training should be designed to ensure that it is appropriate for the target audience. Therefore, in this review, we aim to gain a better understanding of interventions for pre-service teachers that promote SRL and/or SRL support in the classroom.

In order to design an intervention that is appropriate for the target group, suitable intervention content is needed that is relevant for the target group, as well as adaptive pedagogical methods with which this content can be effectively addressed. As the pedagogical characteristics applied in teacher training also have a modelling function (in the sense of a pedagogical two-tier system), the way in which pre-service teachers are taught to self-regulate is essential, because it may influence how they will teach in the future (Gordon et al., 2007).

When talking about pedagogical characteristics, we refer to how learning is conceptualized (e.g., teacher-learner roles, classroom environment, learning beliefs), and therefore how instruction is developed (e.g., methodologies, techniques, and/or tools used for learning). Regarding the content, we refer to the professional competences that pre-service teachers need to master in order to teach SRL properly (SRL knowledge, SRL diagnosis, SRL and learning beliefs, and self-reflection of the teaching practice) (Karlen et al., 2020). In sum, pedagogical characteristics and intervention content related to professional competences must be taken into consideration for the proper design and implementation of SRL interventions. For this reason, in our third research question, we will investigate what are the pedagogical features and content that the SRL interventions address.

Effectiveness of SRL Interventions

At present, there are no clear indicators as to which characteristics make SRL interventions particularly effective (Dignath, 2021). Interventions to promote SRL in pre-service teachers (e.g., Boruchovitch & Ganda, 2013; Kramarski & Michalsky, 2010) are usually based on a comparison between treatment and control groups (e.g., Güvenç, 2010; Tanriseven, 2014), what provides information about the effectiveness of the interventions.

However, only a few studies have compared different treatment groups with different pedagogical characteristics (cf. Kramarski & Michalsky, 2009). This makes it challenging to determine how an effective SRL intervention for pre-service teachers should be designed and implemented. So far, we have a limited understanding of the success and quality criteria for SRL training for pre-service teachers. Which are the important aspects that will help pre-service teachers become more successful as self-regulated learners and, more effective promoters of SRL?

In our research questions four and five, we will investigate which characteristics (theoretical and practical foundations of SRL, pre-service teachers' dual role in SRL and its promotion, and pedagogical characteristics and content related to professional competences) are particularly effective in improving SRL in pre-service teachers.

Aim and Research Questions (RQs)

The aim of this systematic review is to critically assess the effectiveness of interventions that foster self-regulated learning (SRL) and teaching of SRL (T-SRL) among pre-service teachers. By examining the methods and characteristics used in the studies, the extent of SRL and T-SRL development, and the pedagogical implications for pre-service teachers, this review seeks to illuminate effective practices for teacher education and to identify gaps in the current literature. Through these analyses, we aim to contribute to the development of evidence-based approaches for integrating the development of SRL competencies into teacher education, ultimately enhancing teaching effectiveness.

To this end, we explore five research questions (RQ):

RQ1. What models, areas, and strategies do the SRL interventions focus on?

RQ2. Are the interventions based on pre-service teachers' dual role in SRL?

RQ3. What are the pedagogical characteristics and the content of the SRL interventions related to professional competences?

RQ4. What is the effectiveness of the SRL interventions that provide quantitative data?

RQ5. What is the relationship between the characteristics of SRL interventions and their effect sizes?

Method

We followed the PRISMA procedural standards for the development of this systematic review (Page et al., 2021).

Search Strategy

We conducted a search for relevant publications in the two main databases of educational psychology and education research: PsycInfo and ERIC. To address our research questions and cover the whole field of studies, we employed the maximum retrieval strategy by creating two groups of general terms and combining them. The first group included terms used in the literature to refer to teachers in initial training: *pre-service teacher*, *student teacher*, *prospective teacher*, *teacher candidates*, and *teacher training*. The second group included terms referring to

the phenomenon under investigation: *self-regulated learning*, *self-regulation*, *self-regulated strategies*, and *metacognition*.

These search terms were used to find intervention studies in which pre-service teachers should learn about SRL. Accordingly, the following eligibility criteria were established for the literature selection:

- An intervention was carried out.
- Pre-service teachers were the target group.
- The content of the intervention was SRL and/or the promotion of SRL.
- The article was written in English.
- The article was published in a peer-reviewed journal.

The search resulted in 2783 documents, which were reduced to 1795 after removing duplicate references ($n=988$). Following the established inclusion-exclusion criteria (Fig. 1), the titles and abstracts of the 1795 documents were first read, and only articles that included at least one keyword from each of the two groups were chosen ($n=351$). This was followed by the screening phase (Fig. 1), in which an interrater reliability of Cohen's $\kappa=0.72$ was obtained, which can be considered an acceptable value (Landis & Koch, 1977). The screening phase led to 65 articles that met the eligibility criteria. Finally, after the snowball process, i.e., after going through the references of those 65 articles, one more article was added. Lastly, 66 documents (Table 2) were selected for a detailed coding and qualitative analysis.

Data Coding and Analysis

Coding Procedure

A systematic coding scheme was developed following an inductive-deductive procedure. We did content analysis of the theoretical framework (RQ1), design (RQ1, RQ3, RQ4, and RQ5), procedure (RQ1, RQ2, and RQ3), and aim (RQ2) of all the intervention studies, and we derived categories (general descriptive codes, intervention content (e.g., models of SRL, SRL areas, and SRL strategies), teacher's dual role, pedagogical methods (e.g., used methodologies, addressing of SRL beliefs), and content of the intervention (e.g., addressing of SRL knowledge, SRL assessment, self-reflection)). The category creation procedure for each RQ can be found below, and the final categories are found in Appendix 1.

Two rounds of coding were carried out by the first and the second authors. During the initial round, both researchers read the articles and identified relevant categories. The interrater agreement was 57%, indicating a relatively low level of agreement. Consequently, a second round of coding was undertaken to enhance accuracy. In this second round, a modified coding strategy was employed. Instead of reading the entire articles, the researchers focused on specific sections (explained above) where the previously identified information was located. As a result, the interrater agreement in the second round reached 93%.

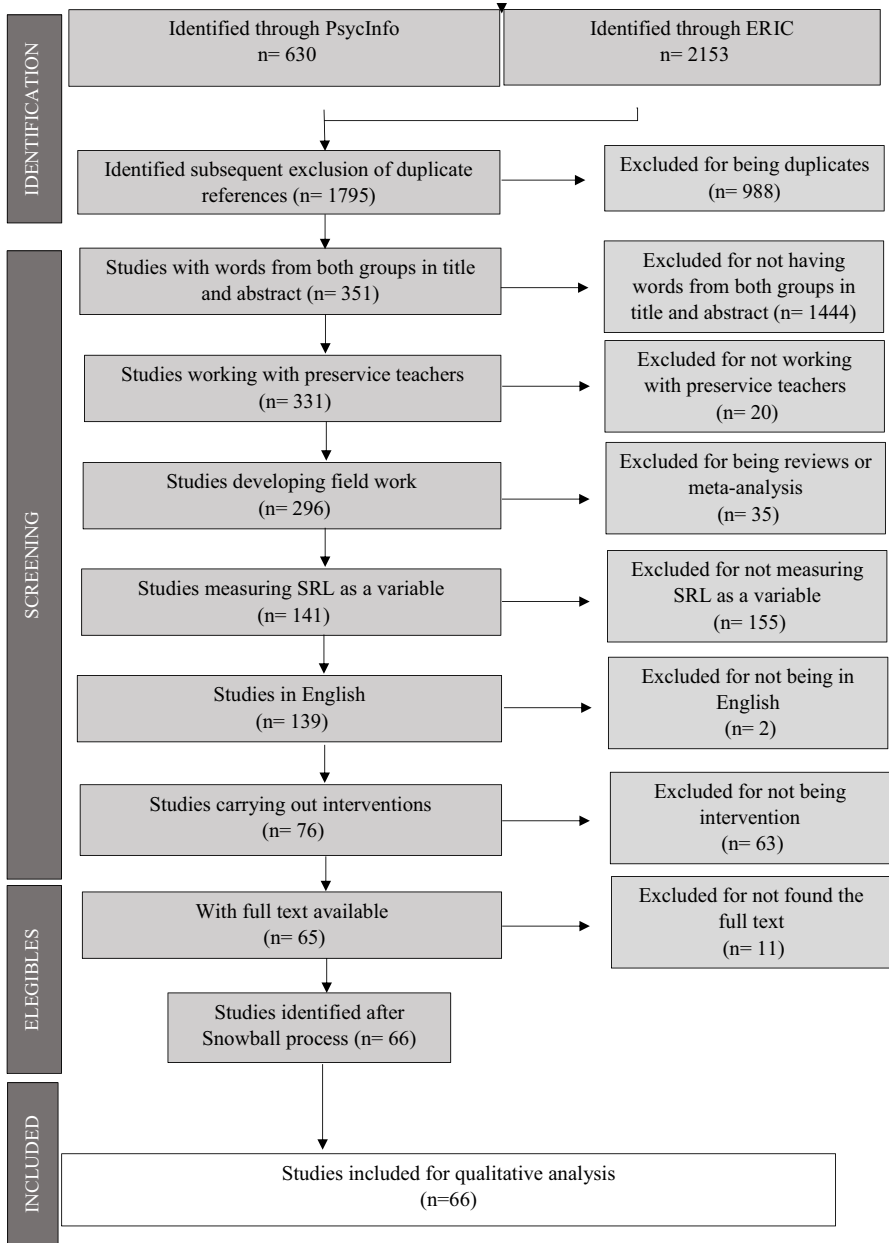


Fig. 1 Document selection through PRISMA

Coding Categories

Regarding RQ1, we identified the models of SRL, SRL areas, and strategies promoted in the SRL interventions. To classify the SRL models cited in the retrieved

Table 2 Included articles' basic information

N	Authors	Year	Country	n	Type of teaching education	N	Authors	Year	Country	n	Type of teaching education
1	Neely	1986	USA	76	Early childhood	34	Malmberg et al.	2015	Finland	103	Not specified
2	Tuckman	1990	USA	126	Elementary	35	Perry et al.	2015	Canada	104	Elementary
3	Kitsantas and Baylor	2001	USA	114	Not specified	36	Quinn and Kennedy-Clark	2015	Australia	205	Elementary
4	Baylor	2002	USA	135	Not specified	37	Hassaskhah	2016	Iran	18	Language
5	Corrigan and Taylor	2004	Australia	6	Not specified	38	Ng	2016	China	38	Early childhood
6	Parsons and Stephenson	2005	UK	22	Early and elementary	39	Seyhan	2016	Turkey	36	High school
7	Anderton	2006	USA	28	Not specified	40	Bruckermann et al.	2017	Germany	63	High school
8	Strijbos et al.	2007	Belgium	31	Not specified	41	Çetin	2017	Turkey	39	Elementary
9	Abd-El-Khalick and Akerson	2009	USA	49	Not specified	42	Engin et al.	2017	Turkey	41	Not specified
10	Järvenoja and Järvelä	2009	Finland	63	Not specified	43	Erdogan and Senemoglu	2017	Turkey	57	Language
11	Kramarski and Michalsky (1)	2009	Israel	194	High school	44	Gencil	2017	Turkey	42	Language
12	Kramarski and Michalsky (2)	2009	Israel	144	High school	45	Kramarski and Kohen	2017	Israel	90	High school
13	Moreno	2009	USA	61	Not specified	46	Malmberg et al.	2017	Finland	18	Elementary
14	Arsal	2010	Turkey	60	High school	47	Pantiwati	2017	Indonesia	59	Not specified
15	Güvenç	2010	Turkey	84	Not specified	48	Yıldız and Akdağ	2017	Turkey	87	Elementary
16	Kramarski and Michalsky	2010	Israel	95	High school	49	Michalsky and Schechter	2018	Israel	132	High school
17	De Jong et al.	2012	Australia	106	Not specified	50	Perez et al.	2018	Spain	163	Elementary
18	Kohen and Kramarski	2012	Israel	9	High school	51	de Jager	2019	South Africa	160	High school
19	Lubin and Ge	2012	USA	60	Not specified	52	Duman and Semerci	2019	Turkey	44	Not specified
20	Vrieling et al.	2012	Netherlands	257	Elementary	53	Kuvaç and Koc	2019	Turkey	51	High school
21	Boruchovitch and Ganda	2013	Brazil	26	Not specified	54	Poitrass et al.	2019	USA	68	Early and elementary

Table 2 (continued)

N	Authors	Year	Country	n	Type of teaching education	N	Authors	Year	Country	n	Type of teaching education
22	Buzza and Allinotte	2013	Canada	108	Elementary and high school	55	Hughes and Partida	2020	USA	11	High school
23	Michalsky and Schechter	2013	Israel	124	High school	56	Isohätäilä et al.	2020	Finland	24	Not specified
24	Seyhan	2013	Germany	31	Language	57	Mansfield et al.	2020	Australia	13	Not specified
25	Tosun and Senocak	2013	Turkey	70	Elementary and high school	58	Michalsky	2020	Israel	102	High school
26	Fernández-Río et al.	2014	Spain	264	Elementary	59	Yıldız	2020	Turkey	41	High school
27	Keller-Schneider	2014	Switzerland	238	Not specified	60	Azizah and Nasrudin	2021	Indonesia	73	High school
28	Panadero and Romero	2014	Spain	218	Not specified	61	Dökme and Koyunlu Ünli	2021	Turkey	57	High school
29	Tanriseven	2014	Turkey	60	Elementary	62	Michalsky	2021	Israel	82	High school
30	Yoon et al.	2014	Korea	46	High school	63	Pieschl et al.	2021	Australia	119	Not specified
31	Huriye	2015	Turkey	113	High school	64	Tasar and Çetin	2021	Turkey	64	High school
32	Inaltun and Ateş	2015	Turkey	127	High school	65	Watt et al.	2021	USA	37	Special education
33	Jado	2015	Jordan	61	Not specified	66	Lee et al.	2022	Korea	140	Special education, early and elementary

articles, we used Panadero (2017) classification as a basis. To sort the SRL areas addressed in the intervention studies, we referred to Pintrich's (2000) model, but made two modifications in order to code our data more accurately. Whereas Pintrich conceptualized cognition and metacognition as one unified area, analyzing the SRL interventions revealed that some of these interventions implemented either only cognitive (e.g., selection and adaptation of strategies) or only metacognitive strategies (e.g., metacognitive awareness training). To be able to compare the effectiveness of interventions focussing on cognitive or metacognitive strategies, we coded these two domains separately. Similarly, we separated the domains of motivation and emotion, which are combined in Pintrich's model, as our analysis of the SRL interventions revealed that motivation and emotion were addressed as distinct processes.

Regarding RQ2, to capture which areas of the teacher's dual role in the context of SRL (Kramarski & Kohen, 2015) the interventions targeted, we coded four different dimensions comprising the dual role of SRL: SRL knowledge, SRL strategy use (pre-service teacher as self-regulated professional), as well as pedagogical content knowledge on how to promote SRL, and diagnose SRL strategy use (pre-service teacher as promoter of SRL).

Regarding RQ3, to investigate the pedagogical characteristics of the interventions as well as the intervention content-related professional competences, we analyzed the procedure sections of the articles to create categories. On the one hand, we classified the pedagogical characteristics into direct and indirect instruction of SRL following the framework of promotion of SRL by Dignath and Veenman (2021) (see Table 3). Direct promotion of SRL refers to the direct instruction of SRL strategies, whereby learners acquire strategies that help them with self-regulation. Indirect activation of SRL refers to the creation of a powerful learning environment in which learners have the opportunity to drive their own self-regulated learning through meaningful activities and cooperation with peers and instructors. Such learning environments should give learners the opportunity to practice self-regulation and take responsibility for their learning, so that SRL skills can be improved (Perry & VandeKamp, 2000; Perry et al., 2006) (see Table 3).

On the other hand, we used the framework of Karlen et al. (2020), to classify the content of the interventions based on the SRL professional competences that teachers need for teaching SRL (see Table 4).

Regarding RQ4, to determine the effectiveness of the SRL interventions, we extracted and/or calculated the effect sizes (Cohen's *d*) of the quantitative studies ($n=53$). Only 12 out of the 53 articles explicitly reported Cohen's *d*. We calculated the effect sizes of the remaining articles ($n=41$). We decided to integrate

Table 3 Categories of pedagogical characteristics

Direct promotion of SRL	Indirect activation of SRL
Interventions work on pre-service teachers' beliefs about learning and SRL	Teacher role: lecturer vs. guidance Learner role: passive, active, cooperative, interactive
Specific methodologies and techniques are used to promote SRL (e.g., metacognitive training)	Interventions used constructivist environment with the aim to promote SRL

Table 4 Classification of interventions' content

Content	Competences
Self-reflection opportunities	Reflection upon professional practice
Use of technology	Pedagogical content knowledge
SRL knowledge	SRL content knowledge/Pedagogical content knowledge/SRL diagnosis
SRL assessment	SRL content knowledge/Pedagogical content knowledge/SRL diagnosis

Cohen's (1988) effectiveness ranges in conjunction with key insights derived from Hattie's (2008) comprehensive findings in his meta-synthesis "Visible Learning." In line with Cohen (1988), we grouped the effect sizes into high effect sizes ($d \geq 0.8$), moderate effect sizes ($d = 0.79-0.5$), low effect size ($d = 0.49-0.21$), and no effect ($d \leq 0.2$). In addition, following Hattie (2008), regarding the practical effectiveness of the interventions, we enlarged the range of moderate effect sizes ($d = 0.79-0.4$) and clustered the low and no effect ranges into one group ($d = 0.4-0$). According to Hattie (2008), averaging all effect sizes across interventions in schools yields an average effect $d = 0.4$. Based on this finding, in pedagogical contexts, effects below $d = 0.4$ can be regarded as the consequence of traditional education and teachers' actions, while only values above $d = 0.4$ represent meaningful deviations that go beyond the effects of everyday teaching (Hattie, 2008; Rosenthal & Wolters, 2000).

Furthermore, as most SRL interventions measured more than one outcome variable and therefore provided multiple effect sizes, we decided that highly effective SRL interventions should have large effect sizes in all the measured variables and moderately effective SRL interventions should have mostly medium effect sizes or values close to high effectiveness in the measured variables. Low-effective interventions would be those with low effect sizes, no effect, or negative effect sizes in the measured variables.

Regarding RQ5, we identified the outcome variables measured in the interventions (SRL, metacognition, motivation, pedagogical skills, and academic performance) and compared them with the following characteristics of the SRL interventions: models, areas, and strategies promoted; implementation of the dual role; pedagogical characteristics; and content based on SRL professional competences.

Results

RQ1. What Models, Areas, and Strategies Do the SRL Interventions Focus On?

RQ1.1 SRL Models

Our analysis revealed that the references to an SRL model occur at three different levels. Few studies ($n = 6$) explicitly framed their intervention within one model. The majority of the studies referred to a model without explicitly anchoring the intervention in a specific model ($n = 34$). Within this group, some studies derived

their interventions from existing interventions on SRL ($n=20$) (e.g., Inaltun & Ateş, 2015, who based their intervention on Clure, Sonak, & Suen's (1999) and Ruiz-Primo, Schultz, & Shavelson (2001)), while a smaller subset of studies ($n=14$) constructed their interventions based on pedagogical theories such as flipped classroom or problem-based learning (e.g., Lee et al., 2022; Yoon et al., 2014). Finally, a third group of articles did not even refer to an SRL model at all ($n=26$).

For the studies that referred to a model ($n=40$), we analyzed whether the choice of a particular model had consequences for the training content (see Table 5). We found that, regardless of the combination of areas promoted by the SRL interventions, Zimmerman's (2000) model emerged as the most frequently cited model (74%), closely followed by Pintrich's (2000) model (67.4%). This suggests that the theoretical model followed by the researchers did not affect the areas promoted within the interventions.

RQ1.2 SRL Areas and Strategies

To answer the first research question, frequencies and percentages of the areas addressed in the interventions and the strategies taught were calculated. The frequencies (f) refer to the total number of strategies of each area that appeared in the interventions. Thus, the frequencies can be higher than the total of interventions ($n=66$), as one intervention can address a wide range of strategies. The percentage refers to the times particular strategies were addressed in the interventions. Thus, the percentages often do not sum 100% per area, as strategies could be addressed in more than one intervention.

The areas addressed by the interventions were unevenly distributed (see Fig. 2). Firstly, the most promoted area was cognition ($n=62$). In terms of the strategies promoted ($f=44$) (see Fig. 3), the interventions paid particular attention to the use of specific cognitive learning strategies (65.9%), such as memorizing, making diagrams, or using organizing materials (e.g., Tosun & Senocak, 2013; Tuckman, 1990).

Second, metacognition was also highly addressed in the SRL interventions ($n=55$) (e.g., Arsal, 2010; Parsons & Stephenson, 2005), and metacognitive strategies were very common ($f=99$). These strategies were related to metacognitive judgement (30.6%) (e.g., self-reflection of learning and teaching practice). However, strategies related to identifying and controlling metacognitive processes (e.g., metacognitive awareness, 16.3%, and adaptive attributions, 3.06%) were rare.

Third, 22 interventions took motivation into consideration (e.g., Buzza & Allinotte, 2013; Mansfield et al., 2020). In terms of strategies ($f=36$), the most frequently promoted strategies were self-efficacy judgements (26.4%) and motivational control (20.5%).

Fourth, 22 interventions focused on behavioral self-regulation (e.g., Moreno, 2009; Strijbos et al., 2007). Of all the strategies ($f=24$), self-observation of behavior was promoted most frequently (45.8%). Few SRL interventions

Table 5 Quoted models and combinations of promoted areas

Combinations	Zimmerman (Z)	Pintrich (P)	Boekaerts (B)	Winne (W)	Hadwin (H)	Efklides (EF)	No model <i>n</i>	<i>n</i>	Final <i>n</i>
1 area									
Cognition	1	1	1	1	1	0	1	2	1
Metacognition	2	2	0	0	0	1	5	7	2
2 areas									
Cog + Met	10	10	4	4	1	0	6	19	13
Cog + Mot	1	0	0	0	0	0	0	1	1
Cog + Beh	1	1	0	1	1	0	0	1	1
Met + Mot	2	1	0	1	0	1	2	4	2
Met + Beh	1	1	0	0	0	0	0	1	1
Met + Emo	0	0	0	0	0	0	1	1	0
Beh + Con	1	1	0	0	0	0	0	1	1
3 areas									
Cog + Met + Mot	2	1	1	3	1	0	0	3	3
Cog + Met + Emo	1	1	1	1	2	0	0	2	2
Cog + Met + Beh	4	4	1	1	0	0	2	9	7
Met + Mot + Emo	0	0	0	0	0	0	1	1	0
Met + Mot + Beh	1	0	1	1	0	0	1	2	1
Cog + Mot + Beh	0	0	0	0	0	0	1	1	0
4 areas									
Cog + Mot + Emo + Beh	1	1	0	0	0	0	0	1	1
Cog + Met + Mot + Emo	1	1	1	1	0	1	0	1	1
Cog + Met + Mot + Beh	2	2	2	2	2	0	0	2	2
Cog + Met + Mot + Con	0	0	0	0	0	0	1	1	0

Table 5 (continued)

Combinations	Zimmerman (Z)	Pintrich (P)	Boekaerts (B)	Winne (W)	Hadwin (H)	Efklides (EF)	No model <i>n</i>	<i>n</i>	Final <i>n</i>
5 areas									
Met+Mot+Emo+Beh+Con	1	1	1	0	0	0	0	1	1
Cog+Met+Mot+Beh+Con	3	3	3	3	0	0	0	3	3
Cog+Met+Mot+Emo+Beh	1	1	0	0	0	0	0	1	1
No areas reported									
							1	2	1



Fig. 2 Promotion of SRL areas in the interventions

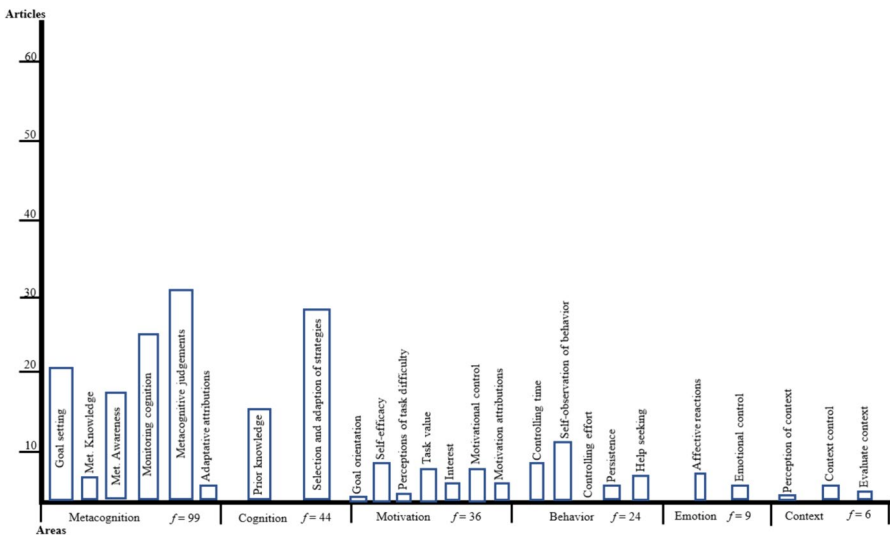


Fig. 3 Promotion of SRL strategies in the interventions

promoted time control (29%) and help seeking (16.7%). Effort-controlling strategies (e.g., persistence, 7.3%, and controlling effort, 0%) were quite unexplored (see Fig. 3).

Fifth, emotion was only promoted in eight interventions (e.g., Boruchovitch & Ganda, 2013; Järvenoja & Järvelä, 2009), and the frequency of the strategies was low ($f=9$).

Finally, self-regulation of the learning context was the least promoted area ($n=6$) (e.g., Fernández-Río et al., 2014; Michalsky & Schechter, 2013). Of the strategies ($f=6$), only context control was promoted.

Apart from the general data on each area, we also observed that SRL interventions combined different areas (see Table 5), and we found that the most frequent combinations were cognition and metacognition (promoted in 19 interventions) and cognition, metacognition, and behavior (promoted in 9 interventions).

RQ2. Are the Interventions Based on Pre-service Teachers' Dual Role in SRL?

Thirteen out of the 66 interventions promoted the dual role of pre-service teachers in the context of SRL. These developed at least one of the subcategories (SRL knowledge, SRL practice) of the self-regulated professional (SRL) and one (teaching SRL, SRL diagnosis) of the self-regulated promoter (T-SRL) (see Table 6). We observed that SRL knowledge instruction is more likely to occur in interventions that promote the dual role of SRL (11 out of 13), in contrast to the studies that examined the role of teacher as SRL professional (learner). In the group of studies that focused only on the teachers as SRL professionals, SRL knowledge was less addressed (6 out of 52). Finally, only three interventions covered all four subcategories (SRL knowledge, SRL practice, teaching of SRL, and SRL diagnosis) of teachers' dual role in the context of SRL (Keller-Schneider, 2014; Kramarski & Kohen, 2017; Michalsky, 2020).

Regarding the outcome variables, the majority of the studies (52 out of 66) aimed to improve pre-service teachers' own SRL skills. However, the focus of the interventions varied. Twenty-three studies focused on training specific SRL skills (e.g., Lee et al., 2022; Duman & Semerci, 2019); on 21 studies, SRL skills were directed at specific knowledge domains, such as natural sciences, languages, and chemistry (e.g., Abd-El-Khalick & Akerson, 2009; Azizah & Nasrudin, 2021; Seyhan, 2016), and 8 studies focused on encouraging pre-service teachers' self-regulation of their professional tasks, such as creating a lesson and establishing learning objectives (e.g., Anderton, 2006; Hughes & Partida, 2020). As previously mentioned, only six out of these 52 interventions targeted the development of pre-service teachers' SRL knowledge (see Table 6). The majority of interventions aimed to activate pre-service teachers' SRL without first explaining what SRL consists of.

Only one study aimed exclusively at promoting the teaching of SRL (Kohen & Kramarski, 2012). The remaining studies that focused on teaching of SRL combined this with a focus on the development of pre-service teachers' own SRL, thus promoting the dual role of teachers in the context of SRL.

Table 6 Interventions focus on teachers' dual role in the context of SRL

Intervention study	SRL*		SRT*	
	SRL knowledge	SRL practice	Teaching SRL	SRL assessment
Nelly (1986)**	x	x		x
Tuckman (1990)		x		
Kitsantas & Baylor (2001)		x		
Baylor (2002)		x		
Corrigan & Taylor (2004)		x		
Parsons & Stephenson (2005)		x	x	
Anderton (2006)		x		
Strijbos et al. (2007)		x		
Abd-El-Khalick & Akerson (2009)	x	x		
Järvenoja & Järvelä (2009)		x		
Kramarski & Michalsky (1) (2009)		x		
Kramarski & Michalsky (2) (2009)		x		
Moreno (2009)	x	x		
Arsal (2010)		x		
Güvenç (2010)		x		
Kramarski & Michalsky (2010)	x	x	x	
De Jong et al. (2012)		x		
Kohen & Kramarski (2012)			x	
Lubin & Ge (2012)		x		
Vrieling et al. (2012)		x		
Boruchovitch & Ganda (2013)	x	x	x	
Buzza & Allinotte (2013)	x			x
Michalsky & Schechter (2013)	x	x	x	
Seyhan (2013)		x		
Tosun & Senocak (2013)		x		
Fernández-Rio et al (2014)		x		
Keller-Schneider (2014)	x	x	x	x
Panadero & Romero (2014)		x		
Tanriseven (2014)		x		
Yoon et al (2014)		x		
Huriye (2015)		x		
Inaltun & Ateş (2015)		x		
Jado (2015)		x		
Malmberg et al (2015)		x		
Perry et al (2015)	x	x	x	
Quinn & Kennedy-Clark (2015)		x		

Table 6 (continued)

Intervention study	SRL*		SRT*	
	SRL knowledge	SRL practice	Teaching SRL	SRL assessment
	Hassaskhah (2016)		x	
Ng (2016)		x		
Seyhan (2016)		x		
Bruckermann et al. (2017)		x		
Çetin (2017)	x	x	x	
Engin et al. (2017)	x	x		
Erdogan & Senemoglu (2017)		x		
Gencel (2017)		x		
Kramarski & Kohen (2017)	x	x	x	x
Malmberg et al (2017)		x		
Pantiwati & Husamah (2017)		x		
Yıldız & Akdağ (2017)		x		
Michalsky & Schechter (2018)		x		
Pérez et al. (2018)		x		
de Jager (2019)		x		
Duman & Semerci (2019)		x		
Kuvaç & Koc (2019)		x		
Poitras et al. (2019)		x		
Hughes & Partida (2020)	x	x	x	
Isohätälä et al. (2020)		x		
Mansfield et al. (2020)	x	x		
Michalsky (2020)	x	x	x	x
Yıldız (2020)		x		
Azizah & Nasrudin (2021)		x		
Dökme & Koyunlu Ünlü (2021)		x		
Michalsky (2021)		x		x
Pieschl et al. (2021)		x		
Tasar & Çetin (2021)	x	x		
Watt et al. (2021)	x	x		
Lee et al. (2022)		x		

*SRL refers to self-regulated learning and SRT refers to self-regulated teaching

**Studies in bold are the ones promoting the dual role

RQ3: What Are the Pedagogical Characteristics and the Content of the SRL Interventions Related to Professional Competences?

Among the interventions with pedagogical characteristics classified as direct instruction (see again the “[Method](#)” section), 43 interventions used specific learning methodologies and techniques (e.g., Pérez et al., 2018), such as metacognitive

training, concept maps, and rubrics (see Table 7). Only five interventions targeted the beliefs pre-service teachers had towards SRL and learning (e.g., Jado, 2015).

Among the interventions with pedagogical characteristics classified as indirect instruction, 34 of the interventions promoted constructivist environments in a variety of ways, such as cooperative learning environments (e.g., Fernández-Río et al., 2014) or problem-based learning (e.g., Tosun & Senocak, 2013). In line with this, pre-service teachers were given opportunities to actively explore, reflect, and seek for learning in almost all the interventions ($n=62$). This was also supported by the person delivering the training, who acted as a guide for learning in 50 of the interventions, as explicitly stated in the studies.

These data show that in terms of pedagogical characteristics, the interventions mainly promoted SRL through indirect instruction. In terms of direct instruction, metacognitive training is used the most.

Regarding the content of the SRL interventions related to professional competences, self-reflection of professional practice was promoted in many interventions (42%), as was the use of technology (38%), in order to train SRL through online tools and environments (e.g., Kramarski & Michalsky, 2010). However, no more than 17 interventions (25%) taught SRL knowledge to pre-service teachers

Table 7 Specific learning methodologies used in the interventions

Categories	Specific methodologies	Total methodologies	Total categories
Techniques	Scaffolding prompts	1	18
	Planning sheets	1	
	Concept maps	6	
	SRL opportunities	1	
	Blogs	2	
	Video analysis	2	
	Portfolio	4	
Metacognitive training	Problematic and successful events	2	17
	Metacognitive prompts	2	
	Metacognitive training	4	
	Case studies	2	
	Learning/reflective journals	5	
	Progress monitoring	2	
Assessment practices	Rubrics	2	4
	Self and peer assessment	2	
Others	Diary	1	4
	Created method	1	
	Practicum	2	

explicitly (e.g., Buzza & Allinotte, 2013), and only six (9%) supported activities that required pre-service teachers to diagnose SRL (e.g., Mansfield et al., 2020).

Regarding the content addressed, we could conclude that SRL interventions hardly addressed content related to SRL content knowledge and SRL assessment.

RQ4. What Is the Effectiveness of the SRL Interventions that Provide Quantitative Data?

Fifty-three studies provided quantitative data. Some of them explicitly reported the effect sizes for their intervention ($n = 12$). We calculated the effect sizes for the rest ($n = 41$). The interventions targeted outcome variables that we classified into five outcome categories: SRL, metacognition, motivation, pedagogical skills, and academic performance (see Table 8).

The distribution of the quantitative SRL interventions was balanced in terms of effect sizes, with a comparable number of interventions in each category: highly effective ($n = 17$), moderate effective ($n = 16$), and less effective ($n = 20$).

Thus, more than a third of the studies reported relatively small effect sizes below $d = 0.4$. Some SRL interventions had no effect on some of the measured variables (Arsal, 2010; Seyhan, 2016; Tosun & Senocak, 2013; Tuckman, 1990). Others even obtained negative effect sizes (Çetin, 2017; Engin et al., 2017; Kitsantas & Baylor, 2001; Kramarski & Kohen, 2017). Moreover, high effect sizes covered a wider range ranging from $d = 0.8$ to $d = 3.12$ (see Fig. 4). Michalsky's (2021) intervention achieved the highest effect size ($d = 3.12$) in metacognitive knowledge, and Pieschl et al. (2021) obtained a high effect size in academic performance ($d = 2.9$). Both interventions trained pre-service teachers to reflect on their own learning (Pieschl et al. (2012)) and teaching (Michalsky (2021)) practice through metacognitive judgements.

RQ5. What Is the Relationship Between the Characteristics of SRL Interventions and Their Effect Sizes?

Only interventions reporting quantitative data ($n = 53$) were considered for answering this research question. This selection was necessary as the studies providing only qualitative data do not give us resources to analyze which are the most effective characteristics of the interventions.

The outcome variables we encountered were SRL ($n = 28$), metacognition ($n = 24$), motivation ($n = 19$), pedagogical skills ($n = 11$), and academic performance ($n = 6$). The mean effect sizes of each outcome variable were calculated by grouping the effect sizes of all interventions by outcome category and effect size. The mean for each group can be seen in Table 9.

Table 8 Interventions effect sizes

N°	Authors	Year	Effect sizes (<i>d</i>)	
Highly effective				
7	Anderton	2006	SRL	1.07
9	Abd-El-Khalick and Akerson	2009	SRL	Regulation of cognition 0.9
				Knowledge of cognition 0.8
11	Kramarski and Michalsky (1)	2009	Ped. skills	Construction of knowledge 1.87
				Design 1.71
			SRL	Cognition 1.07
				Metacognition 0.93
12	Kramarski and Michalsky (2)	2009	Ped. skills	Identifying objectives 2.1
				Selection of content 2
				Planning material 1.9
				Design learning environment 1.8
				Comprehension 1.5
			Metacognition	Planning 1.5
				Monitoring 1.4
				Evaluation 1.3
				Metacognition 1
				SRL Cognition 0.9
16	Kramarski and Michalsky	2010	Ped. skills	Comprehension 1.64
				Design 1.43
			SRL	Cognition 1.07
			Metacognition	0.93
			Motivation	0.85
18	Kohen and Kramarski	2012	Ped. skills	Pedagogy 1.49
				Technology use 1.16
23	Michalsky and Schechter	2013	SRL	Cognition 2.58
			Metacognition	1.37
28	Panadero and Romero	2014	Academic performance 1.47	
			SRL	Forethought phase 1.16
				Self-reflection phase 1.04
			Self-regulation learning 0.88	
33	Jado	2015	Metacognition	Reflective thinking 2.1
				Monitoring 1.48
				Planning 1.3
			SRL	Understanding 1.62
				Help seeking 1.2

Table 8 (continued)

N°	Authors	Year	Effect sizes (<i>d</i>)	
35	Perry et al	2015	SRL	0.9
44	Gencel	2017	Motivation	Attitudes towards the subject 1.2
49	Michalsky and Schechter	2018	Metacognition	Metacognitive skills 0.86
			Ped. skills	Select activities 1.62
				Planning 1.53
				Identify objectives 1.07
52	Duman and Semerci	2019	Metacognition	Understand content 0.8
				Metacognitive aware- ness 1.5
				Metacognitive ques- tioning 1.11
				Metacognitive plan- ning 0.94
56	Hughes and Partida	2020	Metacognition	Metacognitive regula- tion 0.85
				Metacognitive aware- ness 1.1
				Knowledge of cogni- tion 1.03
59	Michalsky	2020	SRT	Regulation of cogni- tion 1
				SRL predicting 2.46
				SRL describing 2.18
				SRL explaining 1.81
				SRL identification 1.54
63	Michalsky	2021	Metacognition	1.73
			Motivation	1.12
			SRL	Cognition 1
63	Michalsky	2021	Metacognition	Metacognitive knowl- edge 3.12
64	Pieschl et al	2021	Academic performance	2.9
			Metacognition	Metacognitive knowl- edge 1.29
				Metacognitive confi- dence 1.11
Moderate effective				
1	Neely	1986	Ped. skills	Class implementation 0.68
8	Strijbos et al	2007	SRL	0.47
13	Moreno	2009	Motivation	0.6

Table 8 (continued)

N°	Authors	Year	Effect sizes (<i>d</i>)		
15	Güvenç	2010	Motivation	Self-efficacy	0.65
				Intrinsic goal orientation	0.43
				Task value	0.43
24	Seyhan	2013	SRL	Elaboration	0.72
				Critical thinking	0.53
				Critical thinking	0.74
			Rehearsal	0.4	
			Peer learning	0.43	
			Effort management	0.43	
			Elaboration	0.25	
			Help seeking	0.08	
			Metacognition	0.73	
			Motivation	Self-efficacy	0.61
Test anxiety	0.48				
Control of learning beliefs	0.09				
29	Tanriseven	2014	SRL	Organization	0.78
				Elaboration	0.7
				Effort management	0.66
				Rehearsal	-0.04
			Metacognition	0.75	
			Motivation	Intrinsic motivation	0.78
			Self-efficacy	0.72	
Test anxiety	0.32				
30	Yoon et al	2014	SRL	Strategy use	0.78
				Strategy consistency	0.78
				Strategy frequency	0.66
				Problem solving	0.59
31	Huriye	2015	Metacognition	Metacognitive skill	0.61
32	Inaltun and Ateş	2015	SRL		0.65
39	Seyhan	2016	SRL	Self-regulated learning strategies	0.56
40	Bruckermann et al	2017	Ped. skills	Experimentation competency	0.5
48	Yıldız and Akdağ	2017	Motivation	Efficacy beliefs	0.45
			Metacognition	Metacognitive awareness	0.43
54	Poitras et al	2019	Ped. skills	Lesson design skills	0.62
60	Yildiz	2020	Metacognition		0.52
61	Azizah and Nasrudin	2021	SRL		0.47

Table 8 (continued)

N°	Authors	Year	Effect sizes (<i>d</i>)		
62	Dökme and Koyunlu Ünlü	2021	Motivation	Attitudes towards the subject	0.53
Low effective					
2	Tuckman	1990	Metacognition	Goal setting	0.18
3	Kitsantas and Baylor	2001	Academic performance		-0.56
			Ped skills	Perceived instrumentality	-0.18
			Motivation	Self-efficacy	-0.56
4	Baylor	2002	Ped. skills	Instructional planning	0.4
				Change in perspective	0.38
				Disposition	0.38
				Perceived instrumentality	0.32
			Academic performance		0.31
10	Järvenoja and Järvelä	2009	SRL		0.25
14	Arsal	2010	Motivation	Self-efficacy	0.36
				Control of beliefs	0.24
				Extrinsic motivation	0.19
			SRL	Rehearsal	0.36
				Elaboration	0.36
				Organization	0.36
				Critical thinking	0.36
				Effort	0.36
				Help seeking	0.36
				Peer learning	0.33
				Text anxiety	0.32
20	Vrieling et al	2012	Metacognition		0.25
			Motivation		0.19
21	Boruchovitch and Ganda	2013	Motivation	Self-efficacy	0.19
22	Buzza and Allinotte	2013	SRL		0.3
25	Tosun and Senocak	2013	Metacognition	Planning	0.07
				Monitoring	0.06
				Evaluation	0.06
			SRL	Information management	0.35
				Debugging	0.0
26	Fernández-Río et al	2014	SRL	Relationships	0.36
			Motivation		0.24
27	Keller-Schneider	2014	Academic performance		0.23
38	Ng	2016	Ped. skills	Interaction with peers	0.28
				Design	0.22
				Video creation	0.12

Table 8 (continued)

N°	Authors	Year	Effect sizes (<i>d</i>)		
41	Çetin	2017	Motivation	0.05	
			Metacognition	Planning and goal setting	0.02
			SRL	Learning strategies	0.01
				Lack of self-directedness	0.36
42	Engin et al	2017	SRL	Learning strategies	-1.04
43	Erdogan and Senemoglu	2017	SRL		0.34
45	Kramarski and Kohen	2017	SRL	Information management	-0.08
				Debugging	-0.36
			Metacognition	Evaluation	-0.01
				Planning	-0.03
				Monitoring	-0.16
			Motivation	Self-efficacy	0.36
Interest and value	0.31				
47	Pantiwati	2017	Metacognition		0.3
53	Kuvaç and Koc	2019	Metacognition	Monitoring	0.38
				Evaluation	0.27
			SRL	Information management	0.29
65	Tasar and Çetin	2021	Motivation	Test anxiety	0.44
				Extrinsic goal orientation	0.36
				Task value	0.29
			Metacognition	Performance management	0.34
				Metacognition	0.34
			SRL	Rehearsal	0.35
				Critical thinking	0.32
	Time and study environment	0.11			
66	Watt et al	2021	Academic performance		0.28

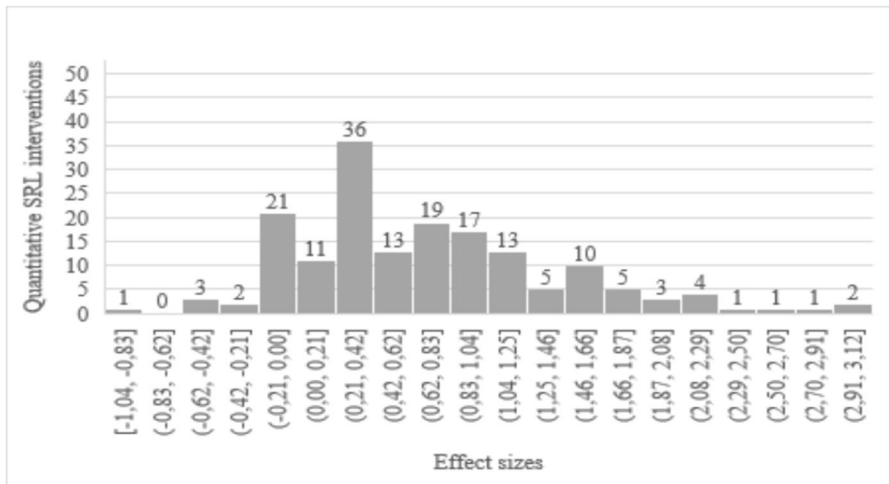


Fig. 4 Distribution of effect sizes in quantitative studies

Table 9 Mean effect sizes and outcome variables

Outcome variables	Mean effect sizes		
	Highly effective	Moderate effective	Low effective
Self-regulated learning	1.16	0.46	0.18
Metacognition	1.32	0.61	0.15
Motivation	0.96	0.55	0.17
Pedagogic skills	1.57	0.60	0.24
Academic performance	2.19	-	0.07

SRL as the Outcome Variable

Twenty-eight studies investigated whether their interventions affect SRL, and ten of these reported a large intervention effect on SRL (see Table 10). In terms of the areas addressed, there is no clear trend in the effectiveness of working on a specific number of areas to improve SRL. The theoretical basis for the design of the intervention is often not reported ($n=5$). In terms of fostering teachers' dual role in the context of SRL, four of the interventions included activities that encouraged pre-service teachers to use SRL as both learners and teachers of SRL. In terms of pedagogical characteristics, the use of specific methodologies was frequent, especially concept maps and learning journals. Finally, self-reflection on the professional and learning practice was the most frequently addressed content area of the interventions ($n=6$).

Table 10 Effectiveness of interventions targeting SRL outcomes

	Highly effective ($n=10$)	Moderately effective ($n=8$)	Low effective($n=10$)
Areas*			
1 area	2	0	1
2 areas	2	3	4
3 areas	2	4	1
4 areas	2	1	1
5 areas	1	0	3
Intervention design foundation			
SRL model	1	1	3
Previous studies	2	1	3
Pedagogical theories	2	2	3
No base reported	5	4	1
Dual role			
SRL learner	6	8	8
SRL teacher	0	0	0
Dual role	4	0	2
Pedagogical characteristics			
Constructivism	2	4	8
Beliefs	2	1	0
Methods and techniques	6	7	5
Interventions' content			
Technology use	3	2	2
SRL knowledge	4	0	4
SRL identification	1	0	2
Self-reflection	6	2	2

*For *areas*, *intervention design foundation*, and *dual role*, the frequencies add up to the total n . For *pedagogical characteristics* and *interventions' content*, the frequencies can add up to more than the total n as each category can be included in more than one intervention

Metacognition as the Outcome Variable

Twenty-four studies investigated if their interventions improved metacognition, with 11 of them reporting a large effect on metacognition after the intervention (see Table 11). Four of the highly effective interventions worked on a single SRL area, which in all cases was metacognition. There was no difference in frequency between interventions that did not report theoretical rationale and those that based their designs on a previous study or on a specific pedagogical theory. Five of the highly effective interventions included activities aimed at promoting the dual role of pre-service teachers as self-regulated learners and as promoters of SRL. The use of specific methodologies, particularly instruction of metacognitive strategies, was frequent in the pedagogical characteristics of these interventions.

Table 11 Effectiveness of interventions targeting metacognitive outcomes

	Highly effective (<i>n</i> = 11)	Moderately effective (<i>n</i> = 5)	Low effective (<i>n</i> = 8)
Areas*			
1 area	4	0	1
2 areas	1	5	4
3 areas	3	0	1
4 areas	2	0	1
5 areas	1	0	1
Intervention design foundation			
SRL model	1	0	2
Previous studies	3	1	3
Pedagogical theories	3	2	1
No base reported	4	2	2
Dual role			
SRL learner	6	5	6
SRL teacher	0	0	1
Dual role	5	0	1
Pedagogical characteristics			
Constructivism	3	1	5
Beliefs	2	0	0
Methods and techniques	5	4	6
Interventions' content			
Technology use	4	1	3
SRL knowledge	4	0	4
SRL identification	2	0	1
Self-reflection	5	2	1

*For *areas*, *intervention design foundation*, and *dual role*, the frequencies add up to the total *n*. For *pedagogical characteristics* and *interventions' content*, the frequencies can add up to more than the total *n* as each category can be included in more than one intervention

Finally, with regards to the content addressed, self-reflection on participants' professional and learning practice was the most frequently trained (*n* = 5).

Motivation as the Outcome Variable

Nineteen studies investigated whether their interventions affected motivation, and five of them reported a large effect on motivation after the intervention (see Table 12). Two of the highly effective interventions focused on training only one SRL area, which in all cases was metacognition. There was no difference in effectiveness between interventions that based their designs on previous studies and those that based them on

Table 12 Effectiveness of interventions targeting motivational outcomes

	Highly effective (<i>n</i> =5)	Moderately effective (<i>n</i> =6)	Low effective (<i>n</i> =8)
Areas*			
1 area	2	1	0
2 areas	1	4	3
3 areas	1	0	1
4 areas	1	1	1
5 areas	0	0	3
Intervention design foundation			
SRL model	1	0	4
Previous studies	2	1	1
Pedagogical theories	2	1	1
No base reported	0	4	2
Dual role			
SRL learner	3	6	5
SRL teacher	0	0	1
Dual role	2	0	2
Pedagogical characteristics			
Constructivism	1	1	3
Beliefs	0	0	0
Methods and techniques	1	5	4
Interventions' content			
Technology use	4	2	2
SRL knowledge	1	1	4
SRL identification	1	0	1
Self-reflection	3	1	4

*For *areas*, *intervention design foundation*, and *dual role*, the frequencies add up to the total *n*. For *pedagogical characteristics* and *interventions' content*, the frequencies can add up to more than the total *n* as each category can be included in more than one intervention

pedagogical theories. As for the promotion of the dual role, three of the highly effective interventions addressed pre-service teachers as SRL learners and as teachers of SRL. Only one of these studies reported pedagogical characteristics (Gencel, 2017). Finally, regarding the content, fostering technology-based environments (*n*=4) and self-reflection on participants' professional and learning practice (*n*=3) were the most frequently addressed aspects in highly effective interventions.

Pedagogic Skills as the Outcome Variable

Of the 11 studies examining the impact of interventions on pedagogic skills, five reported a large effect (see Table 13). Two of these interventions focused on only

Table 13 Effectiveness of interventions targeting pedagogical skills outcomes

	Highly effective (<i>n</i> = 5)	Moderately effective (<i>n</i> = 3)	Low effective (<i>n</i> = 3)
Areas*			
1 area	2	2	0
2 areas	1	0	1
3 areas	1	1	1
4 areas	0	0	1
5 areas	1	0	0
Intervention design foundation			
SRL model	1	0	1
Previous studies	2	2	1
Pedagogical theories	2	0	1
No base reported	0	1	0
Dual role			
SRL learner	3	2	3
SRL teacher	0	0	0
Dual role	2	1	0
Pedagogical characteristics			
Constructivism	2	0	2
Beliefs	0	0	0
Methods and techniques	2	1	1
Interventions' content			
Technology use	4	2	2
SRL knowledge	1	1	0
SRL identification	0	0	0
Self-reflection	5	1	2

*For *areas*, *intervention design foundation*, and *dual role*, the frequencies add up to the total *n*. For *pedagogical characteristics* and *interventions' content*, the frequencies can add up to more than the total *n* as each category can be included in more than one intervention

one area, which in all cases was metacognition. There was no difference in effectiveness between the interventions that based their designs on previous studies and those that based them on pedagogical theories. Two of the interventions promoted the dual role. Information on pedagogical characteristics was only reported in two studies. Lastly, most interventions targeted self-reflection on their professional and learning practice (*n* = 5) and the use of technology (*n* = 4) as intervention contents.

Academic Performance as Outcome Variable

Six studies investigated the intervention effects on academic performance, with two studies reporting a large intervention effect (see Table 14). In these two interventions,

Table 14 Effectiveness of interventions targeting academic performance outcomes

	High effective (<i>n</i> = 2)	Low effective (<i>n</i> = 4)
Areas*		
1 area	1	0
2 areas	0	1
3 areas	1	3
4 areas	0	0
5 areas	0	0
Intervention design foundation		
SRL model	0	1
Previous studies	0	0
Pedagogical theories	0	2
No base reported	2	1
Dual role		
SRL learner	2	3
SRL teacher	0	0
Dual role	0	1
Pedagogical characteristics		
Constructivism	0	2
Beliefs	1	1
Methods and techniques	2	1
Interventions' content		
Technology use	0	2
SRL knowledge	0	1
SRL identification	0	1
Self-reflection	0	3

*For *areas*, *intervention design foundation*, and *dual role*, the frequencies add up to the total *n*. For *pedagogical characteristics* and *interventions' content*, the frequencies can add up to more than the total *n* as each category can be included in more than one intervention

there was no clear trend in the number of areas that were addressed in the intervention. Neither study reported information on the theoretical basis for the design of the intervention. There was also no emphasis on fostering the dual role in either study, as both focused on pre-service teachers as self-regulated learners. In terms of the pedagogical characteristics, both studies used specific methodologies (rubrics and training of metacognitive strategies). Finally, neither of the two studies reported information related to the identified content categories. It is important to note that only two studies showed large effects in this variable. This means that even if these interventions were the ones that improved the outcome variable more, it would be premature to conclude that their characteristics represent the ideal approach to designing an SRL intervention.

Discussion

Our aim was to assess the effectiveness of interventions fostering SRL with pre-service teachers to ultimately shed light on how these interventions should be designed to support pre-service teachers' SRL professional development. For this purpose, we explored five research questions to describe the research field and provide an overview of the effectiveness of intervention characteristics. We synthesized 66 studies from 19 countries including 5587 participating pre-service teachers.

Theoretical Underpinnings of SRL Interventions

Our data indicates that theoretical underpinnings are usually not reported by researchers in intervention studies, and actually theoretical foundation of the studies turned out not to be related to its effectiveness. However, there are some points worth to be highlighted.

As stated in Panadero (2017), frameworks that explain the principles and components of SRL should serve as the foundation for designing interventions aimed at promoting SRL so that SRL development is maximized. For example, the effectiveness of SRL interventions for students has been found to be moderated by the theoretical underpinnings of an intervention study (Dignath et al., 2008). In the analyzed interventions, there are some SRL models that are often cited when contextualizing intervention studies (e.g., Zimmerman (2000), Pintrich (2000)). However, these models are poorly advocated as the underlying approach for developing SRL interventions.

Our analysis reveals that highly effective interventions often lack detailed reporting of their design approach, posing challenges for replication by future researchers and implementation by university teachers without clear guidance. Moderate effective interventions, however, tended to utilize frameworks from previous SRL studies as their design basis. This suggests that while previous studies can serve as a foundation for new interventions, there is a general need for more precise descriptions of the theoretical underpinnings in intervention reports within scientific journals. The appropriate use of a robust foundation will ensure that these interventions are suitable and replicable (Jansen et al., 2019). In the future, SRL interventions should be designed and developed with this premise in mind, in order to investigate whether a theoretical foundation really helps to make SRL interventions effective.

Addressing SRL Areas and Strategies in SRL Interventions

Our findings indicate that interventions targeting specific SRL processes are more effective, focusing on distinct areas rather than adopting a broader approach. This broader scope may increase the cognitive load in pre-service teachers, thus hindering SRL development (Dignath & Veenman, 2020; Sweller, 1994). In contrast,

focused interventions prove more successful. This differs from studies on school-children, where integrating multiple strategies shows greater promise (Dignath et al., 2008; Hattie et al., 1996). The unique benefits of targeted SRL training for pre-service teachers warrant further exploration. Our data show that highly effective interventions predominantly promoted cognition and metacognition. Encouraging specific learning strategies, such as diagram creation and the use of planning templates, along with metacognitive processes like self-reflection and metacognitive prompts, effectively deepened pre-service teachers' learning. This finding aligns with prior research (Dignath & Büttner, 2018). This finding is important because classroom observation research has shown that teachers normally do not include metacognitive instruction in their teaching (Dignath & Veenman, 2021), despite our data showing that metacognitive instruction is effective in teacher training. Can the method used to enhance metacognition in pre-service teachers impede its transfer to professional practice? This question will guide our exploration of the pedagogical characteristics of the interventions, discussed in the last section.

A striking finding is the scant focus on training emotional and contextual regulation in intervention studies, marking a significant research gap given the critical role of emotions in learning. Existing studies on these dimensions are primarily qualitative, which facilitates data collection on emotional and contextual factors but yields minimal insight into intervention effectiveness. Consequently, our understanding of how such interventions enhance SRL in pre-service teachers remains limited. Prior studies underscore the importance of emotional and contextual regulation in effective learning (Dignath & Veenman, 2021; Jansen et al., 2019; Karagiannopoulou et al., 2022; Pekrun et al., 2002). Future research could benefit from employing mixed methods to rigorously assess the impact of SRL interventions that target these areas.

SRL Dual Role in SRL Interventions

It has been argued that teachers' professional development is anchored in their dual role of being SRL professionals and promoters (Dignath & Veenman, 2020; Karlen et al., 2020). It is important then to understand the extent to which this dual role approach is also helpful for the initial training of pre-service teachers to support their professional development. We have found differential effects of the SRL dual role. This is, not all the outcome variables were equally affected when addressing SRL dual role in the interventions. As we have seen, addressing the dual role in SRL in pre-service teachers' training shows promise in enhancing pre-service teachers' SRL skills, metacognition, and pedagogical skills, whereas their impact on motivation remains uncertain, keeping in mind the existing research. Thus, the dual role approach could help pre-service teachers to become better learners and better teachers, but it is unclear if it has impact on their motivation, which is a key factor for success and well-being in academic and professional fields (Schunk, 1995). In the future, experiments should be developed comparing training with one vs. dual role to answer whether teacher training that fosters the dual role perspective of SRL impacts teachers' motivation to become better learners and better teachers.

Pedagogical Characteristics and Professional Competences Related Content of SRL Interventions

Regarding pedagogical characteristics, we found that highly effective interventions promoted direct instruction of SRL (e.g., metacognitive training and the use of learning techniques, such as concept maps). Moreover, our findings confirm that indirect instruction (e.g., arrangement of constructivist learning environments) without being combined with direct instruction is not effective for the development of SRL. This result aligns with previous research (Dignath & Büttner, 2018; Randi, 2004) that demonstrated the effectiveness of direct strategy training. Specifically, Dignath and Büttner (2018) showed that in the context of direct instruction, explicit instruction of strategies (e.g., activities related to SRL knowledge, SRL diagnosis, and SRL beliefs) was highly effective for SRL development. Yet, in line with previous research on school classrooms, the explicit instruction of SRL is rare in SRL interventions with pre-service teachers. Highly effective interventions mainly promoted SRL implicitly (e.g., by using learning journals, metacognitive prompts, etc.). This might be the reason why teachers do not always apply metacognitive training to their teaching practice once they commence their professional careers (Dignath & Veenman, 2021). Teachers may not be aware of SRL strategies since they have not explicitly learned about them during their initial training. Therefore, intervention studies should be developed in which implicit and explicit SRL training is provided to investigate which instruction is more effective, or whether a combination of both should be preferred. In addition, explicit SRL knowledge should be also addressed, to see the effect of its explicit instruction in pre-service teachers.

Regarding the content of the SRL interventions, we found that the most effective practice was to provide pre-service teachers with opportunities for self-reflection of their own learning and teaching practice, thus self-assessment. Through self-assessment practices, pre-service teachers can better monitor their learning and teaching practice and, therefore, reflect on how to improve it. With previous research showing that self-assessment helps students improve their SRL (Andrade, 2019; Nicol & MacFarlane-Dick, 2006), the results of our review now show that the same is true for teacher training. Further research could be conducted to specifically investigate how pre-service teachers self-assess their own SRL.

Summary: Effective Characteristics of SRL Interventions

The data presented in response to RQ5 allowed us to infer the most effective characteristics of SRL interventions and the variables that may be improved by combining these characteristics.

Number of Areas Addressed

Focusing on metacognition as a single area appears to be the most effective approach.

Theoretical Foundation

The theoretical background of the studies does not seem to moderate the effectiveness of the interventions.

Dual Role

The promotion of the dual role in SRL interventions can be highly effective in improving pre-service teachers' pedagogical skills and can also help to improve SRL and metacognition. However, it is important to approach this data with caution, as the dual role is also promoted in less effective interventions when the outcome variables are SRL, metacognition, and motivation. We observed that with SRL and metacognition as outcome variables, the dual role is more present in highly effective interventions, but not in the case of motivation. Thus, addressing teachers' dual role in the context of SRL will help improve pre-service teachers' SRL skills and metacognition.

Pedagogical Characteristics

Direct instruction turned out to be the most effective approach for improving pre-service teachers' SRL, metacognition, and academic performance. Specifically, the use of certain methods such as metacognitive training and learning techniques (e.g., concept maps) appears to be particularly effective. The data also suggests that SRL interventions solely based on indirect instruction are not effective in helping pre-service teachers become better SRL professionals or SRL promoters.

Content of the SRL Interventions

Incorporating self-reflection/self-assessment activities related to pre-service teachers' own learning and teaching practices turned out to be highly effective for improving SRL and metacognition. However, it is not clear which specific content elements make SRL interventions highly effective. In terms of technology use, the data indicates that incorporating electronic tools might be particularly effective in fostering pre-service teachers' motivation. There is also no clear evidence to suggest that training SRL knowledge makes interventions more effective, as both highly and less effective interventions address it. Thus, the impact of targeting SRL knowledge remains inconclusive. Furthermore, the data reveals a lack of emphasis on SRL diagnosis in the interventions analyzed, with only six out of 53 quantitative studies addressing this aspect. Notably, only two highly effective interventions (Michalsky, 2020, 2021) promoted activities focused on pre-service teachers' identification and diagnosis of SRL.

Limitations

This systematic review is subject to a number of limitations that restrict the generalisability of the results, some of which result from the limitations of the

primary studies included in this review. First, our search was limited to pre-service teachers, so that our results may not be generalizable to the training of in-service teachers. Second, we had to exclude qualitative research in the last two research questions because we could not derive effect sizes. Finally, we focused only on specific and isolated SRL interventions that were not embedded in university programs. This limits the generalisability of our results to this type of intervention. In the future, SRL training programs from different universities could be analyzed to investigate whether these characteristics we encountered in SRL-specific interventions are applied in SRL training programs as well.

Recommendations for Research and Practice

We were able to derive four recommendations from our findings, specially from research questions four and five. First, SRL interventions for pre-service teachers need to be specific and should rather focus on a few SRL areas. However, these areas should be covered in great depth and explicitly so that they are fully processed by pre-service teachers and implemented in their subsequent teaching activities. Second, training through metacognitive strategies has been shown to be highly effective. As our data shows, when metacognitive strategies are taught in a more implicit way, the training may have a positive impact on pre-service teachers in becoming better learners, but it may not influence their ability to become better SRL promoters. Third, self-reflection of the learning and teaching practice, thus self-assessment opportunities, appears to be an effective and concrete practice which helps pre-service teachers become better SRL learners and teachers of SRL by supporting their reflection on their learning and teaching practice. Fourth, we saw that promoting teachers' dual role as self-regulated professionals and promoters is an effective perspective for designing SRL interventions that improve pre-service teachers' SRL as well as their pedagogical skills to support their students' SRL development. Based on these implications, there is a need to research whether the positive effect of explicit SRL training not only affects pre-service teachers' own SRL learning, but also, and more importantly, their SRL promotion as self-regulated teachers.

Conclusions

SRL is essential for successful lifelong learning, so its teaching must also be successfully developed. However, there has been a lack of clear guidelines on how teachers can make the teaching of SRL most effective and—as a preliminary step—how pre-service teachers learn this. This review provides an overview on SRL interventions for pre-service teachers that target pre-service teachers' own SRL as well as their future teaching of SRL. It describes the research field, shows gaps in research on this topic, and gives insight into how SRL interventions should be designed and what they should contain so that pre-service teachers are effectively trained in SRL skills and teaching of SRL. This can motivate future research that gives strong emphasis to the dual role of

teachers in the context of SRL and the development of teacher competencies to fulfil both roles and advances the field of research on how teachers can most effectively learn about SRL and the promotion of SRL so that they can effectively teach SRL in their future classrooms.

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Declarations

Conflict of Interest The authors declare no competing interests.

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