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Using learning design and learning analytics to promote, detect and support Socially-Shared Regulation of Learning: A systematic literature review☆

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ABSTRACT

Recent developments in educational technology research underscores the importance of individuals and groups to regulate their own learning processes and behaviours to cope with the fast-changing world around them. This led many researchers to focus on the concept of Socially-Shared Regulation of Learning (SSRL) which tries to understand the different types of collective regulatory processes that emerge while learning in groups. Although initial investigations have predominantly theorised these phenomena, there is a growing need to operationalise SSRL to prepare learners for a future in which regulation of their learning is a key skill for success. This necessitates systematic examination of how Learning Design (LD) and Learning Analytics (LA) can be leveraged to promote, detect, and support SSRL. Therefore, this paper presents a systematic literature review of 110 empirical studies with the aim of identifying: (i) what does empirical literature consider as SSRL; (ii) how is LD used to promote SSRL; (iii) how are LA and LD used to detect SSRL; and (iv) how are LD and LA used to support SSRL. The findings from the literature indicate three major challenges to the operationalisation of SSRL support in the real-world: (i) the lack of convergence in theoretical models, together with the lack of validated instruments for detecting (e.g., coding schemes) and measuring (e.g., questionnaires) SSRL processes; (ii) the types of data most frequently collected and the analysis techniques used make it difficult to provide SSRL support to the students during the learning situations; and (iii) there is a lack of tools designed to promote, detect, and support SSRL processes. This paper describes each challenge, and provides a discussion about potential future research opportunities for tackling them.

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1. Introduction

Collaboration is one of the 21st Century Skills (Voogt & Roblin, 2010), and it is increasingly present both in education and the workplace (Rios, Ling, Pugh, Becker, & Bacall, 2020). In educational contexts, collaborative learning has shown its potential not only to develop conceptual knowledge, but also to foster the acquisition of metacognitive skills (i.e., "learning how to learn") (Smith & Mancy, 2018; Stanton, Sebesta, & Dunlosky, 2021). Metacognition is key while collaborating, since students face many challenges (e.g., differences in goals, priorities, expectations, styles of working or communicating, barriers to create common grounds) that they need to overcome with their peers to achieve the shared learning goals (Kreijns, Kirschner, & Jochems, 2003; Phielix, Prins, Kirschner, Erkens, & Jaspers, 2011). In spite of the importance of metacognitive skills in collaborative learning, the research community has mostly focused on improving cognitive processes related to collaboration (Kirschner & Erkens, 2013). However, recent years have witnessed a surge of research proposals related to the metacognitive aspects of collaboration, studied under the umbrella of the so-called "group regulation" or "Socially-Shared Regulation of Learning" (SSRL).

Research on SSRL aims to study the different types of collective regulatory processes that emerge while learning in groups (Panadero & Järvelä, 2015). It shares foundational theories with the area of Self-Regulated Learning (SRL). SRL studies how learners are responsible for their own learning process, and take control of their cognition, motivation, and behaviour guided and constrained by their specific learning goals, and a set of internal and external conditions (Pintrich, 2000). While SRL is focused on the regulation of individual students, other modes of regulation are also significant and have triggered new areas fields of research including: Co-RL, that focuses on the asymmetric regulation made by one individual to another (e.g., teacher-to-student, student-to-student); and the main topic of this paper, SSRL, that focuses on the regulation of learning in collaborative contexts, where the different members of the group are seen as a unit (Schoor, Narciss, & Körndle, 2015). Although there is no clear consensus on all the facets covered by SSRL (e.g., dimensions, phases, associated terminology), more recent works have tried to propose conceptual frameworks to define all the different aspects of SSRL. For example, according to Järvelä, Gašević, Seppänen, Pechenizkiy, and Kirschner (2020), SSRL **processes** happen when team members take control of the cognitive, behavioural, motivational and emotional **dimensions**. Focusing on the **cognitive dimension**, it is common to consider SSRL processes as a cyclical loop of **four phases** (Malmberg, Järvelä, Järvenoja, & Panadero, 2015): (i) the negotiation of the perception of tasks ("task understanding"); (ii) the creation of objectives and plans ("goal setting and planning"); (iii) the creation of strategies to solve the tasks ("task enactment"); and (iv) the monitoring of progress, and the eventual group adaptation with respect to task understanding, goal setting and planning, and task enactment ("large- and small-scale adaptation"). The **emotional dimension** refers to how group members regulate their interaction in terms of, for instance, how they feel in the group, how these feelings are transferred to communication styles, and how they deal with a positive or a negative environment. The **motivational dimension** handles the differences in terms of personal priorities (e.g., completing goals), levels of participation, and how the group can cope with them. Finally, the **behavioural dimension** refers to how these SSRL processes occur over time, and how groups change their regulatory processes through strategies as a response to challenges, difficulties, etc. Although the SSRL phases are described in a way closely linked to the cognitive dimension, some theoretical models (Hadwin, Järvelä, & Miller, 2017) suggest that other SSRL dimensions are also characterised by metacognitive monitoring, evaluation, and adaptation. It should be noted that this terminology was not well established from the initial research in SSRL, but has evolved while the field matured.

Several works in the literature have shown that carrying out SSRL processes while collaborating contributes to successful performance (Zheng, Li, & Huang, 2017). Nevertheless, many learners lack the regulatory skills required when dealing with complex individual and collaborative activities (Stanton et al., 2021), and SSRL processes seldom emerge spontaneously without support (Miller & Hadwin, 2015). Interestingly, multiple research works, such as Järvelä, Kirschner, Panadero, Malmberg, Phielix, Jaspers, Koivuniemi, and Järvenoja (2015), underline the importance of **"operationalizing"** SSRL processes by: (i) clearly stating the SSRL processes of interest and designing the learning situation in a way that **promotes** them (e.g., including activities in the learning situation likely to trigger SSRL); (ii) **detecting** those cases in which groups are developing (or not) the desired SSRL aspects; and (iii) **supporting** SSRL processes while students are collaborating (e.g., by providing groups with feedback or guidance when the lack of expected or adequate SSRL is observed). The current trend in the research literature towards the operationalisation of SSRL is an interesting departure from previous efforts that have mostly focused on understanding group regulation processes only from a theoretical perspective (e.g., which processes emerge, and how they are related) (Törmänen, Järvenoja, & Mänty, 2021). Recent research suggests that this more practical approach to SSRL can benefit from the possibility of incorporating conceptual and technological proposals made by two well established fields in Technology-Enhanced Learning (TEL) research: Learning Design (LD) and Learning Analytics (LA) (Blumenstein, 2020; Hadwin et al., 2017).

On the one hand, there is evidence that the design of the learning situation (i.e., the definition of the sequence of learning activities, associated learning materials and technological tools, composition of groups, etc.), when carefully planned, plays an important role in the creation of opportunities and constraints for the emergence of SSRL (Miller & Hadwin, 2015). That evidence underlines the promising synergy between SSRL and LD. Although there are different (albeit complementary) views of the LD field (Maina, Craft, & Mor, 2015), this paper considers LD according to Conole and G (2013) definition: "A methodology for enabling teachers/designers to make more informed decisions in how they go about designing learning activities and interventions, which is pedagogically informed and makes effective use of appropriate resources and technologies". Research on LD encompasses the conceptual and technological tools aimed at supporting teachers in the design, sharing, and reuse of pedagogical plans; also known as "learning designs" (Maina et al., 2015).[1] Some recent research studies explore how collaborative learning designs might promote the

[1] Please note that we use the term "learning design", without capitalisation, to denote the pedagogical plan, while "Learning Design" (LD) refers to the research field (Dalziel et al., 2016).

occurrence of potentially effective SSRL processes, as well as their support, by introducing appropriate learning activities, challenges, learning tools, and resources. For example, Järvenoja, Malmberg, Törmänen, Mänty, Haataja, Ahola, and Järvelä (2020b) presented a collaborative learning design to enhance motivation and emotion regulation, incorporating one of the SSRL phases: creating plans and goals collaboratively. The structure of the learning activity aimed to improve students' awareness of the collaborative learning task phases and their regulation of learning.

On the other hand, the detection, and also the support, of SSRL processes can be studied under the lens of LA. LA focuses on the measurement, collection, analysis and reporting of data about learners and their contexts, aiming to understand and improve learning and the environments in which it unfolds (Long, Siemens, Conole, & Gašević, 2011). Several recent research studies (Sedrakyan, Malmberg, Verbert, Järvelä, & Kirschner, 2020; Zheng, Niu, Long, & Fan, 2023c) are exploring the benefits of applying LA techniques to the SSRL domain. Literature shows that detecting SSRL processes is elusive (Järvelä, Hadwin, Malmberg, & Miller, 2018). However, some authors are exploring how data collection and analysis techniques used for other purposes in LA could be used to analyse and support SSRL processes. For example, Emara, Hutchins, Grover, Snyder, and Biswas (2021) presented a systematic analysis framework that combines Natural Language Processing (NLP) methods of collaborative dialogue, analyses of learning tools usage logs, and final scores to better detect students' regulation of collaborative problem solving.

In spite of the high potential of the contributions originated by the LD and LA communities towards a more practical research and application of SSRL, to the best of our knowledge, existing research exploring the use and impact of LD and LA in the promotion, detection and support of SSRL have not been reviewed systematically. There are only three systematic literature reviews on SSRL: (i) the one by Panadero and Järvelä (2015), in which the authors focus on the characteristics of SSRL, how different levels of social regulation could be identified (e.g., co-regulation, self-regulation in cooperation, etc.), the relationship between those processes and learning variables (e.g., performance, quality of collaboration, etc.), and the salient features of SSRL research; (ii) the one by Sulla, Monacis, and Limone (2023), in which the authors analyse the role of teachers' support in promoting SSRL processes; and (iii) the one by Sharma, Nguyen, and Hong (2024), in which the authors reviewed adaptive system environments to foster self-regulated learning (SRL) and SSRL. However, the first two mentioned reviews do not consider the different, and more practical aspects of SSRL mentioned above and mainly focus on theoretical considerations. The third review is very limited in scope, with only 6 papers that study SSRL skills in adaptive learning systems, and does not cover the operationalisation process described here. Moreover, some literature reviews on SRL also cover SSRL aspects, such as the one by Saint, Fan, Gašević, and Pardo (2022). However, it only includes 8 papers related to SSRL (all of them included in this study) and their focus is more concrete than ours, as they specifically analysed the temporal aspects of regulation. Therefore, we believe that the findings of this systematic literature review can be of great interest for the research community on SSRL since its approach to the field, more focused on the operationalisation of SSRL, can help advance towards more pragmatic ways of improving SSRL with the support of technology. Additionally, the LA and LD communities can identify research opportunities for adapting and applying their conceptual and technological proposals to the important field of socially-shared regulation of learning, thus going beyond the support to cognitive processes that they already provide to collaborative learning.

Therefore, in this paper we carry out a systematic literature review following the guidelines proposed by Kitchenham and Charters (2007). We selected 110 empirical studies based on keywords related to SSRL, and extracted different features from them. First, we extracted features related to SSRL dimensions (cognitive, behavioural, emotional, and motivational) and phases studied (i.e., task understanding, goal settings and planning, task enactment, and large- and small-adaptation) to understand the key aspects that can be identified in empirical works. This step aims at shedding light on known consistency issues regarding terminology and models in SSRL research (Schoor et al., 2015). Then, we focused on how LD could promote and support SSRL, e.g., considering the type of activities, their complexity, the explicit inclusion of SSRL processes in the design, etc. Finally, we addressed how LD and LA approaches could help in the detection and support of SSRL including which data relevant to SSRL is collected, how is it analysed, which interventions are proposed, etc. After the extraction of these features, we analysed them in order to answer four specific research questions (RQs, described in Section 2.1), formulated with the aim of understanding how LD and LA are, and can be, used in order to promote, detect and support SSRL. The findings and their implications for research and practice are also reported and discussed.

The structure of the rest of this paper is as follows. Section 2 describes the methods applied to carry out the systematic literature review. Section 3 presents the results of the analysis of relevant publications. Next, Section 4 discusses the main research challenges identified. Finally, Section 5 reports the conclusions of the systematic literature review.

2. Method

This systematic literature review has followed the guidelines by Kitchenham and Charters (2007). In its origin, the approach was created to conduct reviews in the field of software engineering. Nevertheless, it has been widely used in multiple areas, including TEL (e.g., Tabuenca et al., 2021, Pinheiro et al., 2021, Matcha, Gašević, Pardo, et al., 2019, or González-Martınez, Bote-Lorenzo, Gómez-Sánchez, & Cano-Parra, 2015). These guidelines aim to reduce researcher bias by the definition of a protocol. In this protocol, researchers have to clearly: (i) define the research questions they want to answer; (ii) decide the keywords and the digital libraries that are going to be used to collect manuscripts; (iii) define inclusion and exclusion criteria and use them to determine whether the extracted papers could provide direct evidence regarding the defined RQs; and (iv) extract relevant information to answer the RQs. In the systematic review reported in this paper, seven researchers were involved in the execution of the protocol, and no Artificial Intelligence tools have been used in any of the stages. In the following subsections, the different phases of the protocol are described. An overview of the process is graphically depicted in Fig. 1.

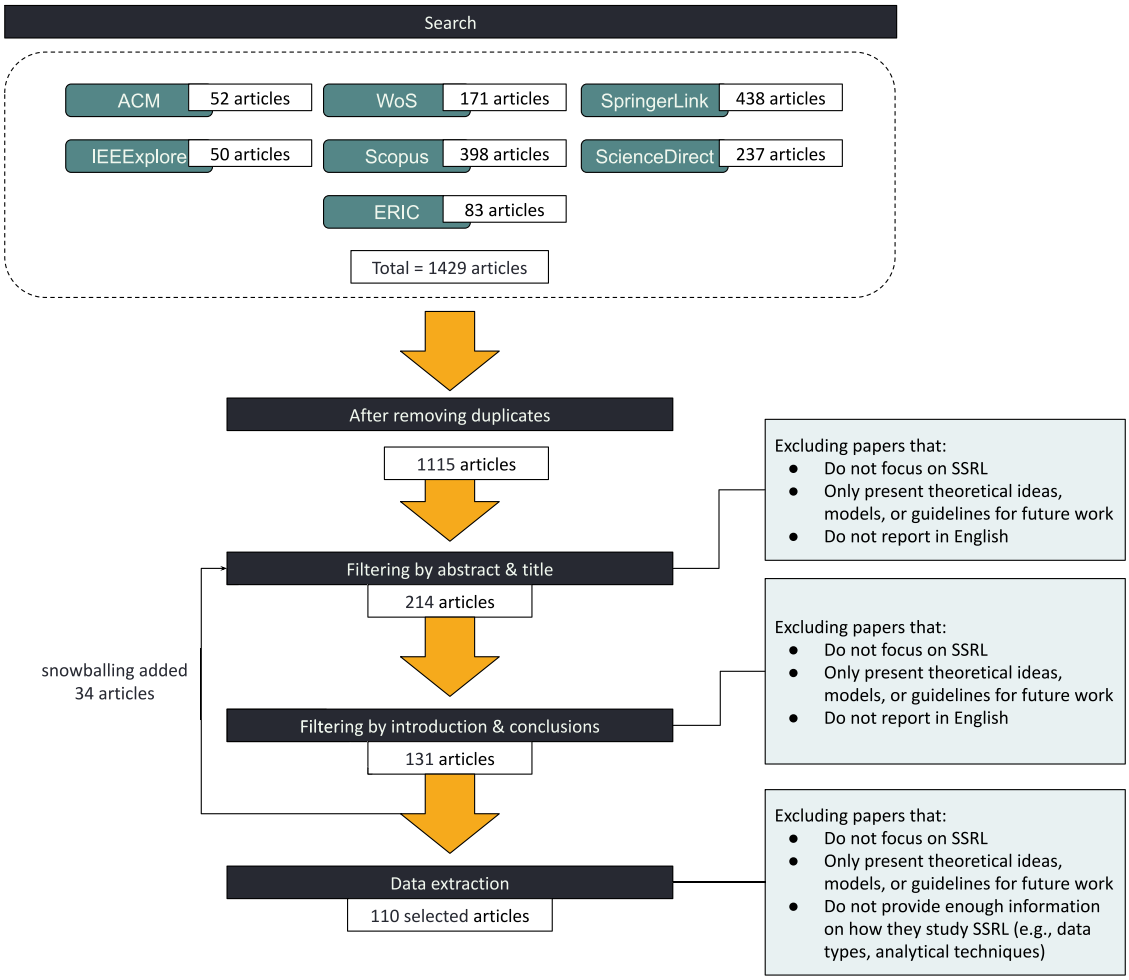

Fig. 1. The method followed in this systematic literature review.

2.1. Research questions

This systematic literature review aims to shed light on the current state of the art of the operationalisation of SSRL processes by promoting, detecting, and supporting them in authentic collaborative learning settings employing LD and LA approaches. As a result, the following research questions guided the study:

1. RQ1: *What do empirical studies consider as Socially-Shared Regulation of Learning?*: existing theoretical models provide multiple facets of SSRL according to its dimensions (e.g., cognitive, emotional and behavioural) and its phases (e.g., task understanding, planning, monitoring, reflection). However, the literature shows an inconsistency in the terminology and models used when doing research in SSRL (Schoor et al., 2015). Therefore, and before tackling the issue of SSRL operationalisation, we review and synthesise models of SSRL that define its constituent processes and how they are linked with LD and LA.
2. RQ2: *How is Learning Design used to **promote** SSRL?*: existing literature suggests that SSRL processes do not easily emerge without help (Miller & Hadwin, 2015). There are different approaches to foster them, for example, including SSRL phases in the learning design by means of specific tasks aimed at triggering regulatory processes, or using specific tools that guide students in those processes. By answering this research question, we want to provide insight into how empirical works have used LD to promote SSRL processes in authentic settings so that students can acquire and develop regulatory skills for collaborative learning. In other words, we want to analyse **how the learning situation has been designed beforehand** to promote SSRL processes.
3. RQ3: *How are Learning Analytics and Learning Design used to **detect** SSRL?*: it is important to understand how data is used to provide evidence on the phases of SSRL. This research question explores how and when existing empirical studies collect and analyse data, and what are the SSRL constructs targeted, for example, dimensions, phases, strategies (e.g., help-seeking, revising a plan, rewarding), modes of regulation (self-, co-, and shared-regulated learning), etc. The overall aim is to relate

all these features with the detection of SSRL processes from a LA perspective. Moreover, information from the learning design can guide the analysis of data (Rodríguez-Triana, Martínez-Monés, Asensio-Pérez, & Dimitriadis, 2015) (e.g., the teachers might have set in their learning design the expected start or end time of a certain SSRL phase, and therefore data analysis might focus especially on set time intervals or set milestones) (Lockyer & Dawson, 2011). Therefore, we have also collected features about the use of LD to guide the analysis of data collected to detect SSRL processes. By answering this research question, we want to provide an overview on **how to detect the different SSRL constructs based on LA and LD approaches** (Martinez-Maldonado, Gašević, Echeverria, Fernande Nieto, Swiecki, & Buckingha Shum, 2021).

4. RQ4: *How are Learning Design and Learning Analytics used to **support** SSRL?*: by means of LD and LA it is possible not only to promote and detect SSRL processes, but also to support them when poor or inadequate SSRL is detected. During the learning situation, data-driven analysis of learning activities (SSRL- or domain knowledge-related) can create opportunities to provide students and/or teachers with feedback for improving SSRL processes (i.e., cognitive, motivational, emotional and/or behavioural aspects) (Hadwin et al., 2017). For example, even if a learning design has explicitly set tasks that involve SSRL processes, the learning analytics-based indicators may show that a group has barely engaged with those desired SSRL processes. Then, a LD- and LA-based support system might: (i) inform the teacher suggesting an intervention; (ii) directly inform the groups to reflect on their lack of engagement; (iii) modify the learning design to reinforce the promotion of SSRL processes; or (iv) a combination of these. Therefore, by answering this research question, we want to provide an overview on **how SSRL processes have been supported during learning activities** through LD and LA approaches.

2.2. Keywords definition and literature search

In this systematic literature review, we performed a broad search since different terms have been used over the years to refer to what is nowadays known as Socially-Shared Regulation of Learning. Our search string had an "A AND B" structure that was:

("socially shared regulation of learning" OR "socially shared metacognition" OR "social regulation" OR "team regulation" OR "group regulation" OR "peer regulation") AND ("collaborative learning" OR "group learning" OR "peer learning")

The "A" component includes the main concepts related to SSRL (e.g., social regulation, team regulation, peer regulation) and a subtopic of SSRL (e.g., socially shared metacognition), while the B component provides alternative expressions regarding learning in groups, since we wanted to exclude cooperative work contexts. We did not include any term related to the constructs studied under SSRL (e.g., dimensions, phases) as our broad search terms appeared to cover all relevant papers with specific references to any specific aspects. In addition, we did not want to introduce a bias towards papers that conform to a certain vision or terminology of SSRL. The search for relevant research literature has been continuously updated up to December, 2023. As illustrated in Fig. 1, the search was performed using 7 different digital libraries, which are prominent in publishing research in the interdisciplinary field of TEL: ACM Digital Library, IEEExplore Digital Library, Web of Science, Scopus, SpringerLink, Science Direct, and ERIC. We retrieved 1429 papers. After suppressing duplicated papers, we ended with an initial set of 1115 papers (see Fig. 1).

2.3. Inclusion and exclusion criteria

After collecting all papers, we defined inclusion and exclusion criteria (IC/EC). We defined IC/EC based on our aim of exploring the impact of LD and LA in the promotion, detection, and support of SSRL in empirical works. Therefore, we included studies with a description of the empirical work including detailed information on the design of the learning situation, the SSRL constructs that were promoted, detected, and/or supported and the data that was collected and analysed to do so. Those papers which studied self or co-regulation in collaborative contexts are excluded as they do not focus on SSRL. Moreover, we included papers that use technology to capture data on collaborative interactions (e.g., cameras, physiological sensors, learning management systems). Publications describing theoretical ideas, models, guidelines for future work or publications that did not focus on SSRL were considered outside the scope of this review. Publications that did not provide enough information about how they studied SSRL constructs were also excluded. Lastly, publications that were not written in English were not included. All these restrictions were formulated as IC/EC, as shown in Table 1.

2.4. Selection and extraction process

Once the selection criteria were defined, we applied them to the set of papers collected. To do so, a multi-step process was followed, as can be seen in Fig. 1:

1. *Filtering by abstract & title*: two researchers independently read the title and abstract of 20% of the papers collected and applied the inclusion and exclusion criteria. When analysing 20% of the papers, the Gwet's AC1 metric (Gwet, 2008) was calculated to measure the agreement between both reviewers. The result showed an agreement of 0.791 (+/−0.056) that, according to the Landis–Koch scale (Landis & Koch, 1977), can be considered a substantial agreement. For the conflicting papers, a third reviewer read the title and abstract, and the three of them discussed the results and the IC/EC. After that, these two researchers applied independently the same IC/EC, each of them to one half of the remaining abstracts and titles. If the reviewers did not have enough information to exclude or include the papers, those papers were not discarded and were considered during the second step. After this step, the set of primary studies was reduced to 214 publications.

Table 1
Inclusion and exclusion criteria.

Criteria	Inclusion	Exclusion
Topic	Publications that focus on regulation in collaborative learning (e.g., Socially-Shared Regulation, group regulation, peer regulation, social regulation)	Publications that focus on self- or co-regulation, even if they are studied in collaborative contexts. Publications that do not focus on regulation in collaborative learning
Empirical work	Studies that have been carried out with students and/or teachers in a collaborative learning context with a specific learning objective	Publications that only presented theoretical ideas, models, or guidelines for future work
Use of technology	Studies that have used technology to capture data about collaborative interactions (e.g., audio recordings, video recordings, sensor data)	Studies that do not use technology to capture data about collaborative interactions
Level of detail	Publications that provide enough information about how they detect SSRL (type of data collected, data analysis methods)	Publications that do not provide enough information about how they detect SSRL
Language	Publications written in English	Publications written in other languages

2. *Filtering by introduction & conclusion*: two researchers independently read the introduction and conclusions of all 214 papers and applied the IC/EC. If the researchers did not have enough information to exclude or include one specific paper, then it was not discarded and was considered during the third step. For the conflicting papers, a third reviewer read the introduction and conclusions and the three of them discussed the results and the IC/EC. This process reduced the set of papers to 131 publications.
3. *Data extraction*: each paper was assigned to two different researchers (among the seven who participated in the whole process) who read them entirely. When reading the entire paper, researchers might have decided to discard it if they considered that any of the EC was met. If not, researchers completed a form to collect all the relevant information from the paper they read systematically. The form was originally guided by the research questions of this SLR, and structured according to the SSRL model presented in Hadwin et al. (2017) and the LA stages (capturing data, analytics and interventions) from Clow (2012). The form was tested and discussed by the seven researchers, using 2 papers for this test. The resulting refined form, summarised in Table 2, was used for the rest of the extraction process. Additionally, when checking the references of each paper, potential papers that were not collected in our search were identified and subjected to the identification of IC/EC (a process known as "snowballing"). The final set of papers included in this review has 110 publications.

3. Results

This section summaries the findings of the systematic literature review based on the 110 selected studies. The attributes extracted for each research question are shown in Table 2. This section begins with the characterisation of the included papers and then reports the results for each research question formulated in Section 2.1, along with some limitations that derive from the data extracted in the review.

3.1. Characterisation of the selected studies

Before deepening into the research questions, it is worth noting that research in SSRL appears to be gaining attention in the research community. As can be seen in Fig. 2, the last 7 years (2017–2023) have witnessed a substantial increase in the number of published SSRL-related empirical studies in comparison to previous years (2008–2017). Regarding the distribution of papers by publication type, the fact that only rather mature papers with empirical results are considered justifies that almost all the selected papers come from journals (103 papers, 93.64%), while only 7 papers (6.36%) come from conferences. Moreover, the right vertical axis of the figure shows the sum of citations per year of the included papers (extracted from Google Scholar). Looking more closely at the number of citations per paper, 27 papers have $10 < n \leq 30$ citations, 13 papers have $30 < n \leq 50$ citations, while 36 have $n > 50$ citations. The most cited papers are shown in Table 3. The two first columns show the top ten most cited papers over the whole period and the corresponding number of citations. As older papers tend to accumulate more citations over time, the table also shows the top ten most-cited articles normalised by the number of years since publication. All in all, it can be seen that the number of citations is relatively high, showing the relevance of the publications in this area to the research community.

Finally, the 110 publications extracted in the systematic literature review were written by 230 different authors. Among them, 34 have published 3 or more publications. According to this classification, Järvelä (24 papers), Järvenoja (17 papers), Malmberg (17 papers), Zheng (8 papers), Dindar (8 papers), De Backer (5 papers), Valcke (5 papers), Volet (5 papers), Törmänen (5 papers), Nguyen (5 papers) are the most relevant authors. Among them, there are strong connections in terms of co-authorship. To explore the possible bias in the results obtained from this SLR, we have taken into account the large presence of papers from one research group (30 papers, 27.27%) and highlighted the potential biases when detected.

Table 2
Overview of the data extraction form.

Field	Description
Title	Title of the paper
Authors	Authors of the paper
Exclusion	Reasons to exclude a paper from the review
RQ1	
SSRL Model	Specify the SSRL theoretical model on which the authors are relying
SSRL Phases	Specify the SSRL phases that the authors are studying (e.g., task understanding, planning & setting goals, task enactment, monitoring, reflection)
SSRL Dimensions	Specify the SSRL dimension that the authors focus on (e.g., cognition, motivation/emotion, behaviours)
RQ2	
Learning Context	Summarise the learning design & context
Explicit mention to the inclusion of SSRL Phases in the learning design	Specify whether the authors explicitly state that they have introduced some or all of SSRL phases in the learning design
Inclusion of SSRL Phases in the learning design (although not mentioned explicitly)	Specify whether the SSRL phases are included in the learning design, although not explicitly stated by the authors
How SSRL Phases LD	Specify how SSRL phases are included in the learning design
Characteristics LD	Specify whether the paper explicitly states any aspect was considered when designing the learning situation
Which Characteristics LD	Specify which aspect was considered when designing the learning situation (e.g., duration, complexity, type of activity)
RQ3	
Data types	Specify the type of data that the authors collect
Data stakeholder	Specify the stakeholder from whom the authors collect the data
Tools	Specify the tools that are used during the learning situation
Time of analysis	Specify when the authors analyse the data (e.g., during the enactment, post hoc)
Analysis techniques	Specify the techniques used to analyse the data
Analysis & LD	Specify whether authors consider the learning design when analysing SSRL
How Analysis & LD	Specify how authors consider the learning design when analysing SSRL
Targeted Constructs	Specify the targeted constructs (e.g., regulatory phases, process of collaboration)
RQ4	
Support	Specify whether support was provided and whether it was the focus of the study
Stakeholder Support	Specify to whom the support was provided
Support focus	Specify what was the focus of the support
Support Type	Specify how was the support being provided and through what means
Support timing	Specify when the support was provided

Table 3
Most cited papers from our review and most cited papers normalised by the number of years since publication.

Top ten most cited papers	Number of citations	Top ten most cited papers normalised by the number of years since publication	Normalised number of citations
Volet, Summers, and Thurman (2009)	639	Volet et al. (2009)	43
Järvenoja and Järvelä (2009)	390	Järvenoja, Järvelä, and Malmberg (2020a)	37
Iiskala, Vauras, Lehtinen, and Salonen (2011)	385	Bakhtiar, Webster, and Hadwin (2018)	37
Rogat and Linnenbrink-Garcia (2011)	360	Malmberg, Järvelä, and Järvenoja (2017)	34
Grau and Whitebread (2012)	294	Iiskala et al. (2011)	30
Järvelä, Järvenoja, and Veermans (2008)	257	Rogat and Linnenbrink-Garcia (2011)	28
Malmberg et al. (2017)	236	Järvenoja and Järvelä (2009)	26
Janssen, Erkens, Kirschner, and Kanselaar (2012)	227	Grau and Whitebread (2012)	25
Bakhtiar et al. (2018)	217	Zabolotna, Malmberg, and Järvenoja (2023)	23
Malmberg et al. (2015)	195	Isohätälä, Järvenoja, and Järvelä (2017)	23

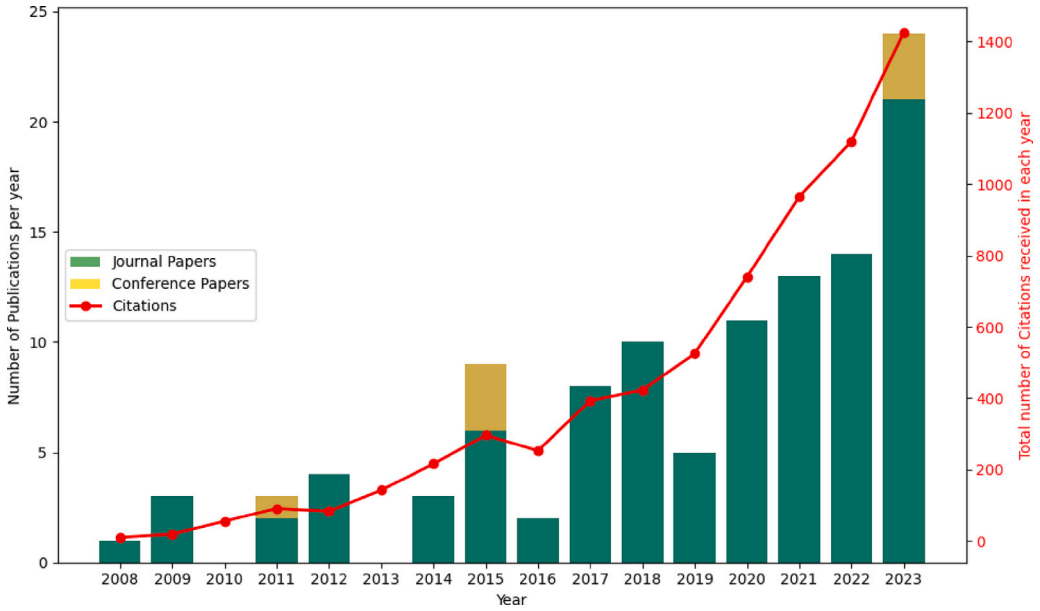

Fig. 2. Evolution of the number of publications (per type) and the number of citations received during each year.

3.2. RQ1: What does the empirical literature consider as socially-shared regulation of learning?

As we mentioned previously, in this research question we wanted to analyse: (i) whether there is consistency in the terminology and theoretical models used; and (ii) which SSRL constructs are the most studied in empirical research on SSRL (e.g., which dimensions and phases). To do so, first of all, we checked whether the studies provided an explicit definition of SSRL. Then, we extracted the theoretical models used in each work, and finally, the different SSRL dimensions and phases studied. Any change in terminology was noted.

Most publications (90 papers) explicitly defined what SSRL is, and only 4 of them used a different terminology when defining regulation in social settings, such as regulation in social interaction (Isohätälä, Näykki, & Järvelä, 2020), intra-group social metacognitive activities (Molenaar, Sleegers, & van Boxtel, 2014), group-level regulation (Vuorenmaa, Järvelä, Dindar, & Järvenoja, 2023), and social regulation (Rogat & Linnenbrink-Garcia, 2011).

Regarding the theoretical models used to ground the SSRL definition, most publications (61 papers) refer to a single theoretical model, while the rest combine two to five. The most frequently used theoretical models can be found in Table 4. As can be seen, the theoretical models presented in Hadwin et al. (2017) and Hadwin, Järvelä, and Miller (2011) are the most common ones in SSRL studies, which accounted for 52 papers in total (3 of them mentioned the two theoretical models), followed by the one presented in Järvelä and Hadwin (2013) with a total of 14 papers (5 of them also used the two previous theoretical models), which also shared the authors and the SSRL concepts. As the main authors explain in Hadwin et al. (2017), the presented theoretical model is an update of the two previous (Hadwin & Oshige, 2011; Järvelä & Hadwin, 2013). These theoretical models stress, among other things, that regulation (regardless of whether the focus is self-, co- or shared-regulation) is multi-faceted and involves taking control of motivation, emotion/affect, behaviour and cognition. These dimensions are not isolated, and they influence one another. Moreover, SSRL unfolds over four loosely sequenced and recursive phases: (i) negotiation of shared perceptions or interpretations of the collaborative task; (ii) negotiation of shared goals, standards, and plans for the task; (iii) coordination of strategic task engagement, collectively and flexibly drawing upon a range of cognitive, socio-emotional, behavioural, and motivational strategies; and (iv) monitoring and evaluation of collaborative processes, progress, and products to intentionally adapt their strategies to optimise the learning processes when needed. Furthermore, the most recent one mentions that regulation during collaboration is informed by three classes of conditions: self-conditions (e.g., individual knowledge and believe, self-perceptions), task and context conditions (e.g., technology, difficulty), and group conditions (the individual perception about the group members or as a whole) (Hadwin et al., 2017).

Regarding the dimensions (also known as facets in some papers), 40.90% of the papers scoped their focus to only one dimension, whereas the rest considered two (24.54%), three (24.54%) or four (1.81%) simultaneously, while the scope of the remaining ones (8.18%) was unclear. The most frequently studied dimensions and the most frequent combinations can be seen in Table 5. As the table shows, the most frequent dimensions are the ones that appear explicitly in the theoretical models explained above, suggesting a quite strong agreement among the reviewed publications regarding which are the key dimensions of SSRL. Indeed, only a few papers (13.63%) diverge from this, which studied “metacognition” and “social” as dimensions. A closer look at these papers shows that they specifically differentiate between metacognitive-related actions (e.g., groups performing task understanding, planning, monitoring

Table 4
Most commonly used theoretical models.

Theoretical models presented in	# of papers (%)
Hadwin et al. (2017)	34 (30.90%)
Hadwin et al. (2011)	21 (19.09%)
Järvelä and Hadwin (2013)	14 (12.72%)
Hadwin and Oshige (2011)	7 (6.36%)

Table 5
Most studied dimensions, individually and in combination.

Dimension	# of papers (%)	Combinations of dimensions	# of papers (%)
Cognition	75 (68.18%)	Cognition & Motivation/Emotion & Behaviour	22 (20%)
Motivation/Emotion	55 (50%)	Cognition & Motivation/Emotion	9 (8.18%)
Behaviour	41 (37.27%)	Cognition & Behaviour	7 (6.36%)
Metacognition	14 (12.73%)	Cognition & Metacognition	6 (5.45%)
Social	3 (2.73%)	Motivation/Emotion & Behaviour	3 (2.73%)

Table 6
Most studied phases, individually and in combination.

Phases	# of papers (%)	Combined phases	# of papers (%)
Monitoring	64 (58.18%)	Task Understanding & Planning & Setting Goals & Task enactment & Monitoring & Reflecting	17 (15.45%)
Planning & Setting Goals	61 (55.45%)	Planning & Setting Goals & Task Enactment & Monitoring & Reflection	7 (6.36%)
Reflection	47 (42.72%)	Task understanding & Planning & Setting Goals & Monitoring & Reflection	4 (3.63%)
Task Enactment	40 (36.36%)	Planning & Setting Goals & Monitoring & Reflection	3 (2.73%)
Task Understanding	36 (32.73%)		

and adaptation) from cognitive-related actions (e.g., reading out loud, summarising, elaborating) and emotion/motivational-related actions (e.g., members of the group supporting or rejecting each others' ideas), while the "social" dimension emphasises that regulation is shared in collaborative learning.

Concerning the SSRL phases studied, Table 6 shows the most frequent ones and their most frequent combinations. As it can be seen, the results suggest that the study of the different SSRL phases is not too unbalanced. However, the fact that task understanding is the least frequent phase captures our attention, since authors such as Miller and Hadwin (2015) highlight the importance of an effective negotiation of the perception of the task and the resources available in order to succeed. It is noteworthy that, when reporting the phases studied, there is much inconsistency in the terminology used. 41 papers used different names to refer to the same SSRL processes, for example, "orientation" is used as "task understanding" (e.g., Ader, Hassane, van Bruggen, & Vermeulen, 2023), "orienting plans" is used for both "task understanding" and "planning & setting goals" (e.g., Fosua Gyasi & Zheng, 2023), "reflection", "adaptation", "evaluation" and "monitoring" are used indistinctively to refer to the process in which group members discuss about their progress during the task and the decisions to make based on that (e.g., Liu, Li, Huang, Lei, & Zhang, 2023). On the other hand, 29 papers study other constructs, such as the challenges that groups face when collaborating and how they relate to SSRL (e.g., Channa, Dindar, Nguyen, & Mishra, 2023), the mode of regulation that arises in the group such as SRL, Co-RL, SSRL (e.g., Bakhtiar & Hadwin, 2020), the regulation strategies that groups follow (e.g., Lobczowski, Lyons, Greene, & McLaughlin, 2021), or the physiological reactions that arise when groups regulate themselves (e.g., Haataja, Malmberg, Dindar, & Järvelä, 2021).

3.3. RQ2: How is learning design used to promote SSRL?

To answer the second research question, we examined the different approaches that have been used to promote SSRL processes through LD. To do so, we have extracted information on the aspects of the learning designs that the authors have considered to promote SSRL processes (e.g., the type of activity, complexity of the task, characteristics of the groups) and the explicit inclusion of the SSRL phases as part of the learning designs, and how they were incorporated.

Interestingly, half of the reviewed literature (54 papers) considers components of the learning designs that are related with the promotion of SSRL. In the LD field there is not a common consensus and various LD frameworks and models propose different sets of potential components and attributes that might be part of a learning design (see, e.g., Dalziel et al., 2016; Persico et al., 2013 for the description and comparison of some of them). Nevertheless, we have identified and summarised in Table 7 those learning design components that are pointed out by the authors of the reviewed papers in relation with the promotion of SSRL and are commonly

Table 7
Characteristics of the learning designs that are considered to promote SSRL.

LD aspect	# of papers (%)
Type of activity	28 (25.45%)
Complexity	21 (19.09%)
Duration	9 (8.18%)
Collaboration pattern	7 (6.36%)
Role assignment	4 (3.63%)
Other	31 (28.18%)

mentioned in the LD literature: type of activity (see, e.g., Laurillard, 2013), complexity (see, e.g., Mor & Mogilevsky, 2013), duration (see, e.g., Pozzi, Ceregini, & Persico, 2016), collaboration pattern (see, e.g., Hernández-Leo, Villasclaras-Fernández, Asensio-Pérez, Dimitriadis, Jorrín-Abellán, Ruiz-Requies, & Rubia-Avi, 2006), and role assignment (see, e.g., Marcos-García, Martínez-Monés, & Dimitriadis, 2015). Regarding the type of activity, some authors explain that, for example, open-ended, ill-structured tasks may require students to activate prior knowledge, negotiate their understandings, and therefore they may afford more planning, monitoring and evaluation than structured tasks (Isohätälä et al., 2020; Molenaar & Chiu, 2014). Another case refers to project-based learning (PBL), not only because they also tend to be open-ended and ill-structured, but because PBL phases overlap with the cyclical model of regulated learning (Nguyen, Lim, Wu, Fischer, & Warschauer, 2021). Thus, offering a multi-phase environment for self- and shared-regulation to unfold (Galand, Raucent, & Frenay, 2010). Tuning appropriately the task complexity is considered a trigger for regulation as, depending on the level of difficulty, students need to explore different regulatory strategies for solving the tasks (Isohätälä et al., 2017). Moreover, there are studies showing differences in the regulation strategies performed by high- and low-performing groups depending on the difficulty perceived by them (Malmberg, Järvenoja, & Järvelä, 2013; Sobocinski, Malmberg, & Järvelä, 2017). As for the duration of the activity, literature has shown that time limitations can add intense pressure to the students and, therefore, promote the appearance of regulatory strategies (Kazemitabar, Lajoie, & Doleck, 2022).

Apart from considering the above factors to promote SSRL processes, several research studies have embedded the SSRL phases, explicit or implicitly, in their learning designs. Specifically, in 33 papers (30%), the authors explicitly explained this decision. On the contrary, in 9 papers the authors did not explicitly mention the inclusion of SSRL phases in their learning designs, but the reviewers were able to identify them in the reported designs. From these 42 papers (38.18%), 30 (71.43%) of them were published between 2017 and 2023, highlighting that the importance of incorporating the SSRL phases in the learning design has been perceived recently, but strongly. As an example of this type of work, in Li, Chen, Su, and Yue (2021) ninety-five college EFL (English as a Foreign Language) students from multiple majors participated in a General English course over 16 weeks. The main objective of the course was to develop students' reading strategies, help them build vocabulary and improve their English writing skills. To do so, they were enrolled in a wiki-supported, literature circle activity. The circles consisted of 4 phases: the preparation phase (task understanding), the within-group collaboration phase (creating a joint plan, deciding roles and discussing), the cross-group sharing phase, and the reflection phase. The groups used an online wiki within Moodle and communicated through asynchronous chats. Another example can be seen in Hadwin, Bakhtiar, and Miller (2018): in this study, 180 undergraduate students enrolled in an elective course on learning strategies for university success. Students were grouped into 3 to 5 members. Each collaborative assignment consisted of three stages: (a) planning, in which learners planned and prepared for the collaborative task both individually and in groups; (b) doing the collaborative task, in which learners had 90 min to complete an online collaborative task via synchronous chat; and (c) reflecting, in which learners were guided to self-assess and reflect on their performance and processes during teamwork. All in all, the fact that in a third of the reviewed papers SSRL is promoted through a purposely adaptation of the learning design opens interesting research lines for exploring effective ways of linking SSRL and LD.

3.4. RQ3: How are learning analytics and learning design used to detect ssrl?

In order to answer the third research question, we focused on how the reviewed research proposals collect and analyse learning data in order to detect SSRL processes and relate them with other constructs (e.g., performance). Specifically, regarding the collection of data, we extracted information related to the types of data collected, the platforms used to collect that data and from whom the data is collected. As for the analysis of data, we extracted information reflecting the techniques used to analyse each type of data, in which moment data was analysed with respect to the learning situation (i.e., real-time, near-time, post hoc), and whether and which information from the learning design was used to guide the analysis. Finally, we extracted the targeted constructs that were detected in each case.

3.4.1. Data collection

The main actors in SSRL are the learners who collaborate in groups. Thus, it is not surprising that all selected works collect data from students. Nevertheless, a few papers also consider data from teachers (8 papers) and researchers (3 papers). In a few cases, teachers could intervene during the collaborative tasks and participate in the discussions of the groups promoting SSRL (e.g., Zhang and Hsu (2021)). In other works, teachers assessed the performance of the groups and then the researchers used the performance assessment results to analyse the differences in the regulatory processes of low- and high-performing groups (e.g., Malmberg et al. (2015)). Finally, in another case, the teachers informed about the context of the learning situation, that was later used to interpret

Table 8
Types of collected data.

Data types	# Papers (%)
Video	55 (50%)
Questionnaire	42 (38.18%)
Audio	21 (30.90%)
Chat logs	21 (19.09%)
Log data from custom applications	20 (18.18%)
Interviews	18 (16.36%)
Data from physiological sensors	11 (10%)
Log data from LMS	8 (7.27%)
Other	33 (30%)

better the results (Ucan, 2017). As for the researchers, they also played a similar role: in Molenaar and Chiu (2014), researchers participated in the discussions of the groups and their interventions formed part of the coding scheme, while in Malmberg et al. (2015) researchers participated in the rating of the final essays.

A summary of the most frequent types of data collected can be seen in Table 8. From this table, we can conclude that the studies on SSRL mostly rely on data from oral and written discourse (video, audio, chats) and self-reports (questionnaires, interviews). A few papers also collect trace data from different technological tools (custom applications, and learning management systems), and others collect data from physiological sensors. It is worth noting that 10 out of the 11 papers reporting their use are published by authors from the same research group, i.e., this incipient trend cannot be attributed to the research field as a whole. The lack of extensive collection and use of trace data, as well as data from physiological sensors, may be attributed to the technical challenges of reliable and valid collection of such data as well as the fact that SSRL is a complex phenomenon that may be not fully understood without the use of self-reported and discourse data (Järvelä et al., 2018).

It is also worth noting that most studies reported in the reviewed papers (81 papers) collect more than one type of data, presumably because researchers need to rely on multiple data sources in order to be able to analyse the multifaceted and complex nature of SSRL, and eventually reach more solid conclusions based on triangulation of multiple types of evidence. While there are several combinations of types of data collected (e.g., questionnaires and audio Kielstra, Molenaar, van Steensel, & Verhoeven, 2022, log data from physiological sensors and video Törmänen, Järvenoja, Saqr, Malmberg, & Järvelä, 2023, questionnaires, interviews and log data from LMS Lin, 2018), there is not a predominant mix. Taking a closer look at the data types, the primary use of video data is to allow the collection, transcription and coding of group conversations. However, in 41 out of 55 papers using video data, researchers took advantage of the associated visual information (e.g., movements or facial expressions) to get more information from the context and improve the analysis. Regarding questionnaires, a more detailed analysis reveals that multiple instruments have been employed in relatively few cases. The most frequent ones are: AIRE, a questionnaire to measure socioemotional challenges (the authors performed variability tests instead of conventional forms of testing reliability, as it measures situation-specific responses) (Järvenoja, Volet, & Järvelä, 2013), and MSLQ, a validated questionnaire to measure the motivational and self-regulation state of the students (Pintrich et al., 1991). AIRE was used 6 times out of 42 uses of questionnaires, while MSLQ was used 5 times. Nevertheless, in Kazemitabar et al. (2022), the authors adapted section three of the AIRE instrument for measuring the shared emotion regulation strategies that teams applied to regulate their team emotions at times of experiencing challenges. The original questionnaire included items for measuring more aspects, such as self-regulated emotions and co-regulated emotions, but they only kept the ones focused on socially-shared emotion regulation. In addition, they explained that the original questionnaire had a limited number of items for measuring it, so the list of items was further expanded. In Bakhtiar et al. (2018), the authors presented the Socio-Emotion Sampling Tool (SEST) and Socio-Emotion Reflection Tool (SERT), two questionnaires to extract information about: (a) individual group members' current emotional states and plans for regulating those emotional states; (b) judgements of their emotional states; (c) satisfaction with the group's progress; (d) perceptions of the collaborative experience (a-b are linked to SEST, while d is associated to SERT). The rest of the works used different ad hoc questionnaires aligned with their research (e.g., questionnaires to measure metacognitive awareness, challenges during collaboration, cognitive load). This finding suggests that there is no consensus about which questionnaire to use when studying the SSRL phenomenon and, as a consequence, it shows the need to create and validate questionnaires to measure the different constructs of SSRL (e.g., dimensions, phases).

In the few cases in which trace data is employed (26 papers, 23.63%), researchers collect it through the learning tools that students use when doing their collaborative tasks. In this review, three types of learning tools have been identified: (i) general tools to support learning, such as Moodle, as a learning management system (Su, Li, Hu, & Rosé, 2018); (ii) tools designed to support collaborative learning, for example: Tencent QQ (Zhang, Chen, Wen, Chen, Gao, & Wang, 2021a), Collabucate (Lobczowski et al., 2021), Ontdeknet (Molenaar et al., 2014), WeChat Zhang, Liu, and Lee (2021b), Google Docs (Bakhtiar & Hadwin, 2020). These tools provide communication channels, allow the organisation of activities, sharing documents, etc.; (iii) tools specifically designed to support SSRL: S-REG, VCRI combined with OurPlanner and OurEvaluator, SEST, SERT (Järvelä, Kirschner, Hadwin, Järvenoja, Malmberg, Miller, & Laru, 2016). These tools are questionnaires embedded in the digital platforms that allow students to reflect about their cognitive, motivational and emotional state individually and in groups. They rely on the questionnaire mentioned previously, AIRE (Järvenoja et al., 2013). However, although 61 works use different tools to collect data, none of them is predominant. Therefore, there is an opportunity to create tools that collect different types of data, not just self-reported, that can be used for promoting, detecting and supporting SSRL processes.

Table 9
Frequency of the techniques used per type of data.

Data type	Technique (# papers)	Combination of techniques (# papers)
Video	Manual coding (50) Descriptive statistics (46) Inferential statistics (31) Machine learning (12)	Manual coding & Descriptive statistics & Inferential statistics (22) Manual coding & Descriptive statistics (12) Manual coding & Descriptive statistics & Inferential statistics & Machine learning (8)
Questionnaire	Descriptive statistics (31) Inferential statistics (23) Manual coding (17)	Manual coding & Descriptive statistics & Inferential statistics (9) Manual coding & Descriptive statistics (5) Descriptive statistics & Inferential statistics (5)
Audio	Manual coding (20) Descriptive statistics (17) Inferential statistics (10) Machine learning (6)	Manual coding & Descriptive statistics & Inferential statistics (8) Manual coding & Descriptive statistics (4) Manual coding & Descriptive statistics & Machine learning (3)
Chat logs	Manual coding (20) Descriptive statistics (17) Inferential statistics (8) Machine learning (5)	Manual coding & Descriptive statistics & Inferential statistics (6) Manual coding & Descriptive statistics (6)
Log data from custom app	Descriptive statistics (13) Manual coding (9) Inferential statistics (6) Machine learning (6)	Manual coding & Descriptive statistics & Machine learning (3) Manual coding & Descriptive statistics & Machine learning (2)

3.4.2. Data analysis

The information extracted shows that all papers analysed the data after the learning situation, i.e., post hoc. It is worth noting that four papers included the use of S-REG (e.g., Järvenoja et al., 2020a), three of them included the use of Collabucate (e.g., Lyons, Lobczowski, Greene, Whitley, & McLaughlin, 2021), both tools mentioned in the previous subsection, and five more use other platforms (e.g., Zheng, Long, Niu, & Zhong, 2023b). In these cases, students received the results from the analysis done by the platforms in real time (e.g., their motivational state), but the main analysis of their research was done post hoc. The fact that most of the studies detect the SSRL processes after the learning situation implies that the groups cannot be supported during the activity, at least not taking into account what is happening to their particular group. Therefore, there is a lack of methods that may analyse the data in real-time (or near-time) to eventually provide actionable information during the enactment.

Regarding the techniques used to carry out data analysis, a summary of the most frequent ones, as well as the most frequent combinations, can be seen in Table 9. As it shows, in most cases, data is coded manually and then descriptive analysis and/or inferential statistics are performed. Deepening in the manual coding technique, we have analysed the different coding schemes that researchers use. Interestingly, most studies used their own coding scheme (49 papers) based on the definitions and codes of previous ones, such as Rogat and Linnenbrink-Garcia (2011), Winne and Hadwin (1998) or Iiskala et al. (2011). The fact that there are not predominant coding schemes, but modifications in the definitions and codes of previous ones, highlights the need to establish a clear basis of the SSRL processes that are expected to occur during collaboration, and that might enable the comparison of research results among different studies. From the 30 works that employ machine learning techniques, most of them use process mining and sequence mining techniques (22 papers), e.g., (Vuorenmaa et al., 2023) in their analysis to extract the behavioural aspect of SSRL (e.g., the evolution of the regulatory processes over time). Clustering (5 papers, e.g., Törmänen et al., 2023) and regression techniques (4 papers, e.g., Kim & Lim, 2018) are also used, but less frequently. Finally, only two very recent papers make use of NLP techniques that may help alleviate the burden of the manual coding (Zheng, Long, Chen, & Fan, 2023a; Zheng et al., 2023b), thus opening a new line of research. It is also worth pointing out that 9 out of 12 papers that use machine learning to specifically process video data belong to the same research group. However, when considering the 30 papers that use machine learning for any purpose, only 10 belong to the above mentioned research group, suggesting that machine learning techniques are evenly employed across the SSRL community.

Additionally, we were also interested in assessing the extent to which the learning design was considered when analysing or interpreting SSRL phenomena. While 73 studies did not consider the learning design when analysing SSRL, there were 37 papers that, to some extent, had taken it into account. For example, monitoring events were discussed in relation to task-specific events (Malmberg, Haataja, Seppänen, & Järvelä, 2019), data in the reflection phase was discussed along with the reported challenges (Hadwin et al., 2018), and interactions (utterances) were categorised according to the processes defined in the learning design (e.g., problem-solving processes) (Kim & Lim, 2018). The learning design was also used by Lobczowski et al. (2021) in order to select the most challenging sessions to analyse video, and Näykki, Isohätälä, Järvelä, Päysä-Tarhonen, and Häkkinen (2017) presented the results according to each of the SSRL phase included in the task. In Zhang et al. (2021a), the tasks and phases defined along the weeks guided the interpretation of the evolution of regulation events. All these works provide a substantial evidence on how LD can, not only be used for promoting SSRL processes, but also for interpreting them. Finally, there are 13 studies that analyse the effect of the support given to the students (more details in Section 3.5). In these cases, the differences in the learning design of the experimental and control groups were used to guide the analysis and interpret the results (e.g., Silva, Mendes, Gomes, & Fortes, 2023).

Table 10
SSRL constructs studied.

SSRL constructs	# Papers (%)
SSRL phases	49 (44.55%)
Regulatory dimensions	41 (37.27%)
Modes of regulation	40 (36.36%)
Regulatory strategies	17 (15.45%)
Other	79 (71.72%)

Concerning the targeted SSRL constructs, Table 10 shows that "SSRL phases" (e.g., task understanding, monitoring) are the most frequent studied. Detecting one or several dimensions (i.e., cognition, motivation, emotions, and behaviours) is also very frequent, as well as analysing the mode of regulation (i.e., SRL, CoRL, SSRL), while there are fewer works targeting SSRL strategies (e.g., help-seeking, adopting a new tactic, rewarding). Moreover, these constructs are also studied in relation to other learning metrics, explaining that 79 papers study "other" constructs. Specifically, how they relate to performance (e.g. the final score obtained in the learning activity) is the research goal of 24.54% of the papers (i.e., they try to understand how the presence or absence of certain elements of regulation affect the grades). Less prominently, 12.72% of the works also study the relationship between SSRL and the process of collaboration (e.g., the relation between the steps that groups perform and their regulation of learning). Finally, 11.82% deal with how challenges (i.e., moments in which the groups face any kind of cognitive, metacognitive, emotional or behavioural problem) promote SSRL processes. The variety of constructs is highly related to the fact that there are no predominant coding schemes, as the coding schemes determine which SSRL constructs are expected to be detected. This relationship, together with the fact that the analysis of SSRL processes were carried out post hoc, reflects that there is still a significant research effort needed to better understand SSRL processes and to empirically verify the associated theories.

3.5. RQ4: How are learning design and learning analytics used to support SSRL?

In order to answer the fourth research question, we focused on the papers that use LD (e.g., specific learning activities, scripts, tools) and/or LA (i.e., LA indicators) to provide feedback or make the students reflect on their SSRL processes, so that they can improve them.

The results suggest that these issues are largely unexplored: only 15 papers include SSRL support during the learning activity. Among them, 14 papers report mechanisms of supporting the group as a whole, while only 6 of them provide additional support to the individual within the group. The support is provided mainly through prompts (7 papers) and visualisations (7 papers). In 14 cases, support is delivered through custom applications or systems during the learning situation, while in Quackenbush and Bol (2020) the support is provided through the teacher.

As an example of visualisations and prompts as a supporting mechanism, in Järvenoja et al. (2020a), 44 higher education students worked with a collaborative assignment. They used the S-REG tool to trace individual and group's emotional, motivational and cognitive states in different moments of the sessions. The tool provided a visual representation using a traffic light metaphor, where a green light indicated that everything was fine, a yellow light indicated some challenges or unclear situation, and the red light indicated severe challenges and need for regulatory actions in one of the states. The results of the study suggested that the S-REG tool balanced collaboration by prompting the groups to regulate emotions and motivation right at the beginning of the motivational and emotional challenging learning session. Another example can be seen in Lyons et al. (2021): in this work, the authors presented Collabucate, a web-based tool for fostering social regulation in collaborative learning. The tool was created according to Järvelä et al. (2015) design principles, and it provides SSRL support to the students. Specifically: (i) it promotes metacognitive awareness of students' learning process by asking the students to rate their own and the group's cognition, motivation, and emotion, and to identify the current group challenges; (ii) it supports the externalisation of learning processes by displaying the students' self-reports on a dashboard, comparing individual answers with group answers, and asking the individual members to externalise their evaluations; (iii) it promotes the acquisition of regulatory processes by incorporating an script in which the individuals had to explain how they would implement group strategies, and how the group would implement the group strategy; and (iv) it explicitly teaches group regulation strategies by providing personalised, just-in-time, instruction on a group strategy corresponding to their self-identified current challenge.

Moreover, from the 15 papers that explore the use of LD and LA to support SSRL, 10 of them reported the effects of their intervention. For example, in Zheng et al. (2023b) students had to create a poster using Photoshop. To do so, they had a learning platform that included a chat. For the experimental groups, the platform also included a tab to see group feedback. This group feedback was generated automatically using information from their chat, that was processed by a NLP method to classify the events as cognitive, metacognitive, behavioural, and emotional engagement. Once the engagement indicators for each dimension was calculated, the system compared them to the averages, and provided the group with feedback in form of messages informing of their indicators and giving tips. The results suggested that using the platform with the incorporated mechanisms to provide feedback increased the engagement in SSRL processes without increasing the cognitive load of the students. In any case, these results suggest that, when compared with promotion and detection, the support of SSRL is still quite underexplored, a fact that might open interesting research lines in the short term

3.6. Limitations of the extracted data

The selection of papers and the data extraction carried out during this review have some limitations. First, this work is limited by the restrictions of the keyword search, and the exclusion of non-English texts, which may exclude some relevant studies. Also, we have not reported information on the educational context of the reviewed studies (age of students, knowledge domains, group sizes, face to face vs online, etc.), even if we extracted it from the papers. The reason is that, in most cases, authors do not provide explicit reasons for choosing their specific context, nor reflect on the impact of this context in their findings. Furthermore, we have not reported information on ethical and data privacy issues. Although we have collected information on these aspects, the authors only reported information on whether the students gave their consent to participate in the study, or whether the research was approved by an Ethical Committee. Therefore, the research ethics of studies was well covered, but it was not possible to delve into aspects such as to what extent it is ethical to offer differentiated support to specific students, or to what extent students' privacy is ignored.

4. Discussion and open research gaps

The systematic literature review reported in this paper aimed at better understanding how empirical works (110 papers) have operationalised the SSRL processes by promoting, detecting and supporting them in collaborative learning settings using LD and LA approaches. The results suggest that this research area is still in an initial state with regards to trying to operationalise SSRL processes (see Section 3). From the analysis carried out, we highlight three major research challenges essential for evolving from a more theoretical research on SSRL to a more actionable, potentially impactful approach that support SSRL through LD and LA.

4.1. From theoretical models to empirical frameworks: challenges and opportunities

Despite the fact that half of the papers rely on the theoretical models presented in Hadwin et al. (2017), Hadwin et al. (2011) and Järvelä and Hadwin (2013), showing some convergence in the definition of the phases and dimensions to be studied by SSRL, there is still a non-negligible number of papers that use different theoretical models when doing research on SSRL. For example, some papers use theoretical models created for self-regulated learning (Winne & Hadwin, 1998) and adapt them for social settings, while others use theoretical models created for Socially-Shared Metacognitive Regulation, presenting different constructs to be studied (e.g., micro-level of metacognitive regulation processes involved in problem solving) (Iiskala, Volet, Jones, Koretsky, & Vauras, 2021). This problem was stated by Schoor et al. (2015) and Panadero and Järvelä (2015) in 2015, and nine years later it still remains as relevant and persistent.

The fact that there is not a complete convergence of the theoretical models to be used is emphasised by the fact that most of the papers use their own coding schemes for detecting SSRL constructs. As a result, there is an explosion of different terminology to refer to similar concepts, resulting in a lack of clear definitions of the SSRL constructs that can be promoted, detected, and supported. Moreover, there is a lack of validated instruments to measure SSRL processes. Most of the works do not use scales specifically designed to measure SSRL, but utilise different instruments (validated or not) for other purposes (e.g., SRL, metacognitive awareness, self-efficacy, feeling of difficulty). Therefore, there is a problem of comparability of the different studies that comes with an opportunity for SSRL researches to standardise and validate instruments for detecting (e.g., coding schemes) and measuring (e.g., questionnaires), that become widely adopted by the research community.

Finally, the promotion (and not only the understanding) of SSRL processes also calls for the development of more practical, theory-driven, but also LD-driven, frameworks to promote SSRL processes. Some works in the area of self-regulated learning have started to create protocols and frameworks that aim at grounding SRL high-level constructs into concrete actions taken by the students (Siadaty, Gasevic, & Hatala, 2016). For example, Saint, Whitelock-Wainwright, Gašević, and Pardo (2020) presented a framework for analysing micro-level processes of SRL based on trace data. Specifically, the authors presented a mapping between the actions taken by the students (e.g., sequences of clicks in their Learning Management System) and the macro-level processes defined (i.e., planning, engagement, and evaluation and reflection). These approaches also face a validation challenge - to what extent can we be sure that they actually detect SRL/SSRL processes? More recent works in the area of SRL have attempted to address this issue. For example, Fan et al. (2022) used a similar approach to Saint et al. (2020) to map digital traces to SRL constructs. In addition, they asked students to follow a think-aloud protocol to analyse whether the sequences of actions related to specific SRL processes matched the students' self-reports. Although think-aloud protocols have their own drawbacks (e.g., they increase students cognitive load), their use as "reference points" for the analysis of trace data, together with leveraging LD elements to promote concrete SSRL processes and using multimodal data (e.g., discourse data, self-reports), can be a promising starting point for operationalizing SSRL.

4.2. Lack of mechanisms to support SSRL during collaboration

As we have seen in Section 3.4, most papers analyse the data post hoc. This approach does not enable to provide support to the students in their SSRL processes during the collaboration. This is strongly related to the types of data collected (oral and written discourse data, and self-reports) and the type of analysis performed for each type of data. On the one hand, oral and written discourse data (video, audio, and chats) have been analysed using primarily manual coding to detect SSRL processes. It is well known in the literature that using manual coding is really time consuming (Dönmez, Rosé, Stegmann, Weinberger, & Fischer, 2005), hindering real time support. Moreover, it is subjected to the interpretation of the researchers, which may result in significant biases (Dönmez

et al., 2005). An alternative to reduce such risks is to use other approaches to code these types of data, such as NLP or AI-based systems, which are yet largely unexplored in the SSRL field. Nevertheless, it is also worth noting that the use of these methods on video, audio or chat data may raise certain ethical and privacy concerns (Yan et al., 2024). On the other hand, literature has shown that self-reported data conveys the presence of student biases (Saint et al., 2020), increment their cognitive load (Fincham, Gašević, Jovanović, & Pardo, 2018) and prevents observing the evolution of the regulatory processes during the collaboration, as it is collected at specific points in time (Winne & Perry, 2000). To overcome this limitation, some authors have proposed the use of data coming from physiological sensors (see, e.g., Nguyen, Järvelä, Rosé, Järvenoja, & Malmberg, 2023), providing promising results but also raising significant ethical and practical concerns (see, e.g., Giannakos, Cukurova, and Papavlasopoulou (2022)). Another type of data available, though barely used in the reviewed papers, is digital trace data, such as log data from custom applications and Learning Management Systems. This type of data (e.g., clicks on LMS, interaction with documents, forums, etc.) has the disadvantage of being difficult to be linked to high-level constructs such as regulatory processes. However, the literature shows that the use of information from learning designs has the potential to assist in the mapping between the data obtained from the technology used and the SSRL processes (Martinez-Maldonado et al., 2021), even more when the learning design has been used to promote specific SSRL processes. Moreover, there is an opportunity to conduct studies that triangulate the information obtained post hoc from questionnaires and discourse data with the information reflected in the traces, interpreted with the help of the learning design, so that researchers could better understand how to give semantics to the traces. An advantage of using this type of data is that it allows real-time analysis, and facilitates the reproducibility of the research. There are preliminary proposals in the field of SRL that can inspire SSRL researchers. For example, in the study by Salehia Kia, Hatala, Baker, and Teasley (2021), the authors structured the information provided in the LMS following a template to incorporate task-specific sub-goals, aiming to create visible and meaningful markers of students' SRL processes. To develop what the authors name "proximal indicators" of SRL processes, they took the trace data generated by the students in the LMS and had an expert map those sequences to specific SRL processes. Then, the authors collected a new dataset in a different course, including an embedded pop-up survey in the LMS, that prompted students to report what they were doing at certain moments, thereby helping to validate the derived proximal indicators of SRL. Therefore, exploring ways to promote concrete SSRL processes that translate into actions loggable by the learning platforms, validating them through multimodal data (as discussed in section 4.1), and then analysing this data in real time, can pave the way to support SSRL during the learning situation. This research could be strongly fostered if authors would share their (anonymised) datasets along with their learning designs, so as to better understand their findings, and apply alternative methods. This alignment with open science principles has been detected only in recent papers in the SSRL community (e.g., Li et al., 2024).

4.3. Lack of tools to promote, analyse and support SSRL in different learning contexts

As a result from the previous challenge, there are almost no tools designed to promote, detect, and support SSRL. Moreover, the most commonly used tools, S-REG and Collabucate (both described in Section 3.5), rely on self-reported data, whose drawbacks have already been discussed. The tool proposed by Zheng et al. (2023b) makes use of the students' group chat logs and automatically classifies the conversations using NLP methods, which allows them to display in real time the engagement that students have with planning, monitoring, reflection, and evaluation SSRL phases, among other aspects (e.g., cognitive engagement). Nevertheless, the creation of tools specifically designed to operationalise SSRL processes is still largely unexplored. A potential research line could be focused on how to design a tool/architecture/system to operationalise SSRL that could be used in different domains (e.g., making use of annotations in the LD that would allow similar semantic information to be obtained from data from different courses with similar structure). This would imply the proposal of LD processes (and associated design tools) that might eventually help designers make decisions aimed at promoting and supporting SSRL (Villa-Torrano, Vitiello, Shi, Rosé, Asensio-Pérez, Dimitriadis, Gómez-Sánchez, & Bote-Lorenzo, 2023).

Furthermore, although it is not necessarily linked to the creation of tools to operationalise SSRL, the review shows the need to move forward in the study of SSRL interventions and the impact they have. In our review, 10 out of 15 papers offering support for SSRL study the effect they have, but more research is needed. Also, at this point, no study offers support to the teacher, thus opening up another line of research opportunity. Finally, it would be desirable to include stakeholders involved in the research cycle in order to provide more value in the support provided in such SSRL interventions and tools.

5. Conclusions

After having analysed 110 papers (out of 1429 initially found by our search criteria, plus the snowball process), this review has shown that there is a partial convergence in the SSRL theoretical models, with a consensus in the dimensions and phases to be studied, which nevertheless has not yet allowed researchers to agree on standardised and validated instruments for detecting (e.g., coding schemes) and measuring (e.g., questionnaires) SSRL processes. Moreover, it has shown that using LD to promote SSRL processes is becoming more relevant in recent years. There are several approaches to this end, such as aligning the SSRL phases with the learning design, generating challenges during the learning activity, or generating prompts to foster the emergence of these processes, thus presenting an emerging research line. The review indicates that there is still a lack of mechanisms to support SSRL during the development of the learning situation, mainly due to the limitations of the data collected and the techniques used to analyse them. As a consequence, there are very few conceptual and technical tools aimed at specifically supporting SSRL, which makes it difficult for students to receive the necessary guidance to better develop their SSRL processes. Furthermore, more studies that analyse the effectiveness of the support they offer are also needed. Finally, while the reviewed studies were carried out in

a variety of contexts (e.g., group sizes, knowledge domains, face-to-face vs online), we could not extract an analysis on how this context affects the ways SSRL is promoted, detected, and supported, as the authors did not provide explicit reasons for choosing their specific context, nor reflect of the impact of this context in their findings. Hence offering an opportunity for more research in this line.

CRediT authorship contribution statement

Cristina Villa-Torrano: Writing – review & editing, Writing – original draft, Visualization, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Wannapon Suraworachet:** Writing – review & editing, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Eduardo Gómez-Sánchez:** Writing – review & editing, Methodology, Investigation, Data curation. **Juan I. Asensio-Pérez:** Writing – review & editing, Methodology, Investigation, Conceptualization. **Miguel L. Bote-Lorenzo:** Writing – review & editing, Methodology, Investigation, Funding acquisition, Conceptualization. **Alejandra Martínez-Monés:** Writing – review & editing, Methodology, Investigation, Funding acquisition, Conceptualization. **Qi Zhou:** Writing – review & editing, Methodology, Investigation, Conceptualization. **Mutlu Cukurova:** Writing – review & editing, Methodology. **Yannis Dimitriadis:** Writing – review & editing, Methodology, Funding acquisition, Conceptualization.

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Supplementary data

Supplementary material related to this article can be found online at https://doi.org/10.1016/j.compedu.2025.105261.

Data availability

The research data for the article can be found in the following link: https://uvadoc.uva.es/handle/10324/75101.

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