A literature review on Self-Regulated Learning and Personal Learning Environments: Features of a close relationship

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ABSTRACT: This article analyzes the relationship between self-regulated learning (SRL) and personal learning environments (PLE) in light of the educational academic literature of the decade 2010-2020. The SRL and PLE concepts have been important in contemporary discussions in educational psychology and educational technology respectively. This study uses a systematized literature review followed by a qualitative analysis of the most cited literature to establish a narrative that highlights and deconstructs the close relationship between learners' SRL skills, and their capacity to develop and refine their PLE. For this purpose, in this analysis we explore (1) the presence of the PLE concept in the 200 most

referenced papers published on SRL, and (2) the relationship between the two concepts, as they appear in the 20 most frequently cited articles that include both of them. Results show that SRL is linked to an educational and mixed perspective on the PLE concept, and that a variety of designs and platforms exist for teaching strategies linking SRL and PLE in educational practices. In-depth analysis suggests a series of features that reveal the influence of SRL in the PLE concept, reflected in the following themes: laying foundations, offering models for interrelated work, extending digital platforms with social networks, extending learning activities with e-portfolios and pedagogical strategies, and extending knowledge by exploring students' usages and strategies. Conclusions address recommendations for further work to explore these features and the manner in which they can extend the features of the relationship between PLE and SRL.

Keywords: self-regulated learning, personal learning environments, literature review, technology, qualitative analysis

1. Introduction

In this paper, we explore the relationship between two related concepts of importance in contemporary discussion regarding education and learning: self-regulated learning (SRL), and personal learning environments (PLE). Although a logical overlap between facets of the two concepts exists and is reflected in various individual studies, we are unaware of any work that examines multiple studies in order to define the contours of the relationship between SRL and PLE. To advance understanding of these two concepts and how they have influenced or could influence each other, we conducted a two-phased, systematized literature review of all work from 2010-2020 addressing both concepts.

PLE do not represent a novelty *strictu sensu*; the first reference including the term in the SCOPUS database appeared in 1977, in relation to the use of Artificial Intelligence for the creation of "personal" learning environments tailored to individuals (Miller & Goldstein, 1977). Nevertheless, it was in 2008 that the quantity of literature on PLE began to grow dramatically as new technologies increased the presence of PLE in education (Dabbagh & Castañeda, 2020). The PLE concept is an attempt to represent how people learn using the relationships, resources, mental configurations, tools, and services on offer in the current digital era (Castañeda & Adell, 2014) and has been connected with the notion of learning inside formal education structures, as well as outside (Attwell, 2021; Carrasco-Saez, et al. 2019; Yen, et al. 2019; Xu et al., 2020). The PLE concept is also associated with the possibilities that digital technologies offer

for the building of learning environments (Attwell, 2007; Attwell, 2019; Dabbagh & Castañeda, 2020; García-Martínez, et al. 2020). From the outset, the PLE concept sparked debate regarding the very nature and scope of the term, with varying degrees of emphasis on its most educational aspects and its technological elements (Serhan & Yahaya, 2022). More recently, the importance of the PLE concept has only increased with widespread uptake of remote teaching (Attwell, 2021; Pedro & Santos, 2021). Also, research has noted the mixed results of some uses of PLE (Attwell et al., 2013; Castañeda & Tur 2020; Xu, Zhu & Chan 2020).

However, the impact of the PLE concept in general topics on education, beyond the limits of the educational technology (EdTech) field, is as yet unclear (Pedro & Santos, 2021; Cosgrave, 2021). One important educational concept that would appear to overlap in interesting ways with PLE is self-regulated learning (SRL; Serhan & Yahaya, 2022). According to literature reviews by Castañeda et al. (2019) and Castañeda et al. (2022), SRL represents one of the three most important focus points of publication in the education literature in recent years, with the other two main focus points being teacher professional development and emergent teaching practices.

SRL is understood to have various components, including metacognition, management of cognitive strategies, and behaviour (Zimmerman, 2000). It includes all the cognitive processes that allow the learner to take control of their behaviour, motivation, and metacognition in order to learn, as well as to make decisions regarding how to improve learning (Zimmerman, 2002). Learners involved in SRL apply a repertoire of strategies to academic tasks (Lim & Newby, 2021) in the different phases of learning, mainly to plan, monitor, and self-assess learning (Pérez et al., 2018). SRL emphasizes the importance of learner autonomy and requires learner self-assessment and self-awareness regarding academic strengths and weaknesses (Perifanou & Economides, 2021).

Both the SRL and PLE concepts are abundantly mentioned in the scientific literature on education, and many papers reveal connections between the two. PLE research frequently includes SRL as a keyword or related concept, and assumes that the ability to build, enrich and develop a PLE is closely related to an individual's metacognitive skills for self-regulated learning (Attwell et al., 2013; Castañeda & Adell, 2014; Dabbagh & Castañeda, 2020; Ramírez-Mera & Tur, 2021). The exploration of how SRL and PLE are linked to each other is worthwhile because it can sharpen understanding of both concepts and may also offer practical implications. Furthermore, both SRL and PLE are closely related to *learning to learn*, a competency widely acknowledged as being of great importance in the present and future (e.g., European Union, 2018). It has also been proposed that users with SRL abilities are better prepared to take advantage of their PLE (Xu et al., 2020), and that SRL and PLE both may be essential to effective lifelong learning approaches (Tu et al., 2018).

Therefore, we set out to explore if PLE and SRL are conceived as related concepts and the extent to which the extant literature defines and explores this relationship. In particular, how has SRL influenced the evolution of the PLE concept, and vice versa? Consequently, this study aims to analyze the relationship between SRL and PLE in academic literature using a systematized review. This is done firstly by analyzing the presence of the PLE concept in the most referenced papers on SRL over the last decade, and secondly, with a meta-narrative review approach (Zawacki-Richter et al., 2020), that allows us to explore the articles that include both PLE and SRL and that might be considered of greatest impact over the same period.

2.   Method

2.1 Research question

In alignment with the study aims, the research question is formulated as follows:

> RQ. What are the features of the relationship between PLE and SRL in the literature of the greatest impact linking both concepts in the 2010-2020 decade?

In order to answer this question, we need to explore the presence of the PLE concept in the academic literature published over the last decade (2010-2020) and its relevance and characteristics in the literature of greatest impact that links SRL and PLE.

2.2 A systematized literature review

In order to answer the proposed research question, the researchers conducted a systematized literature review (Grant & Booth, 2009). The objective of such a review is to "provide examination of recent or current literature" going "beyond mere description to include a degree of analysis and conceptual innovation" in a more methodologically flexible approach than a *systematic* review (Grant & Booth, 2009, p. 95). These kinds of reviews are frequently used in the social sciences, and are built on systematizing and quality criteria (Booth et al., 2012). The review procedure followed the 8-step protocol defined by Okoli and Schabram (2010), combined with the literature review phases described in McMillan and Schumacher (2009). This procedure has also been used in Castañeda et al. (2022).

Figure 1.

Procedure of literature review (Castañeda et al., 2022).
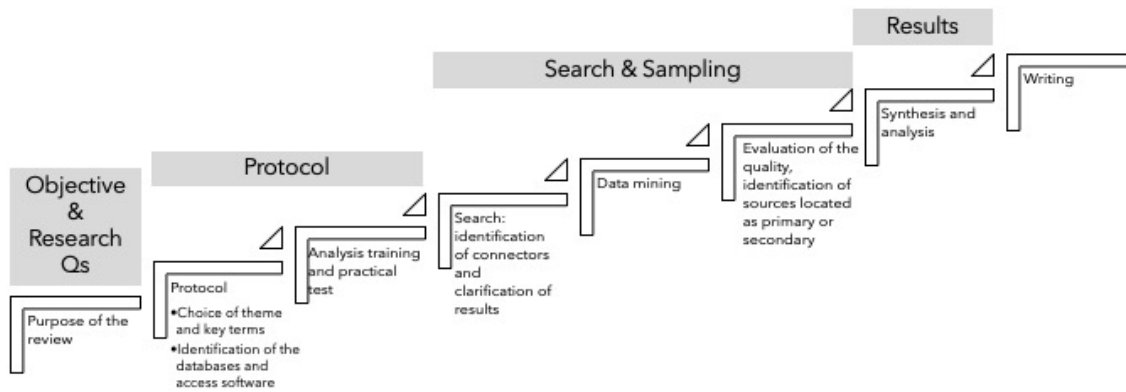

2.2.1 Protocol

The sampling process began with a search in Web of Science (WOS) of all items classified under the topic of 'education.' From these, we selected the 100 most cited articles, and we observed SRL was one of the three most recurrent topics. The complete sampling process for this preliminary stage of review is explained in Castañeda and Tur (2020) and Castañeda et al. (2022). Next, in order to frame the key terms for this particular review, and refine and optimize the following steps of the search process as much as possible, the key topic of our analysis (SRL) was broken down into its main areas and alternative terms were proposed for each of the components (Figure 2):
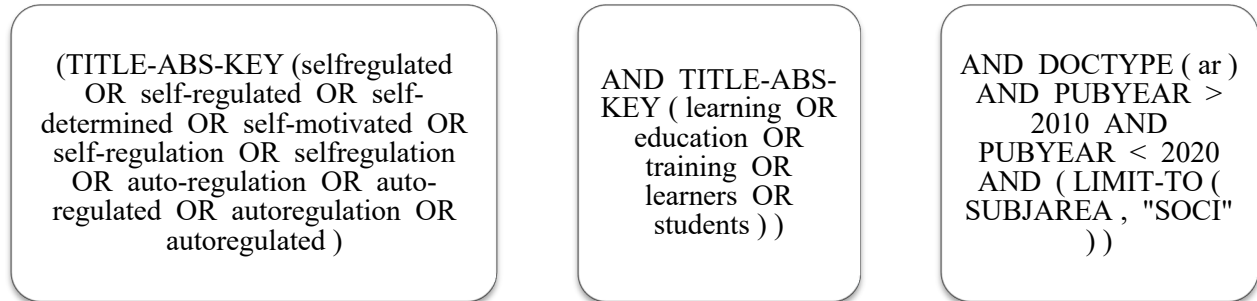
Figure 2.

Simple approach to the SRL semantic field (Castañeda et al., 2022).
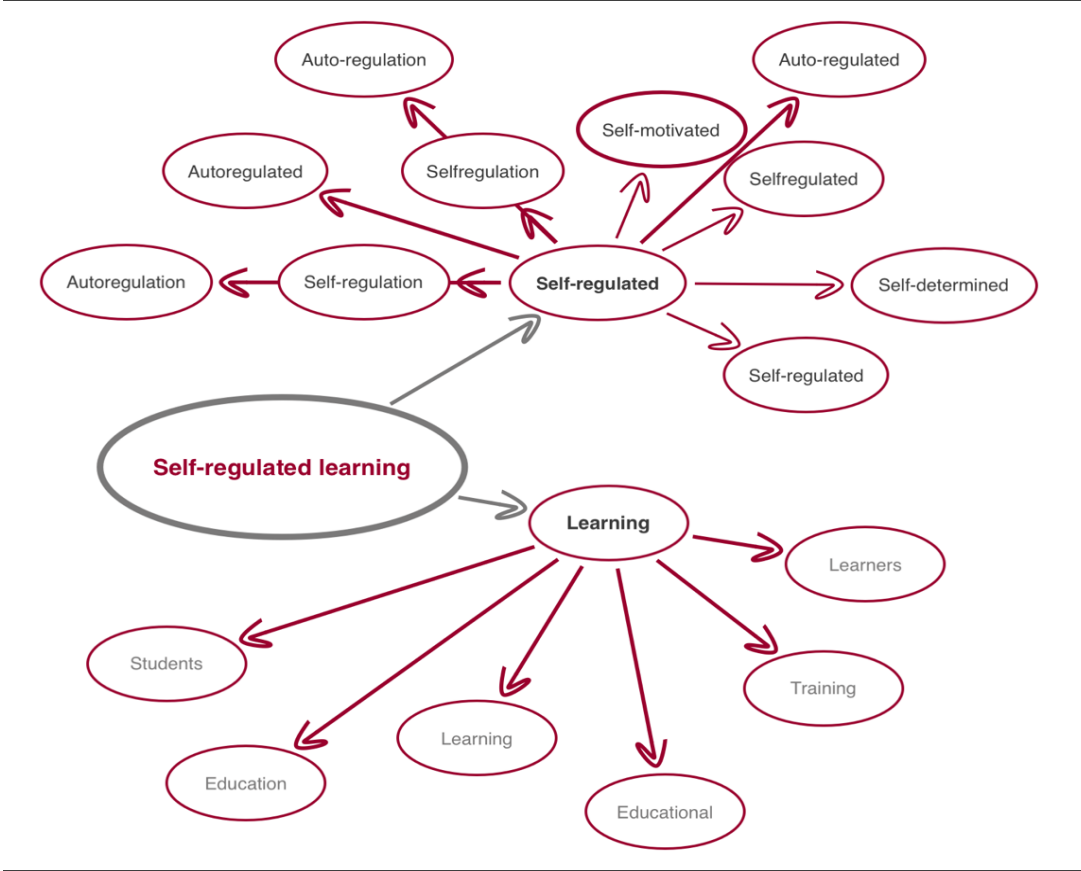
Consequently, based on this approach, the Boolean search was created (Figure 3) and used in three different databases -WOS, SCOPUS and Google Scholar- as principal search systems (Gusenbauer & Haddaway, 2020).

Figure 3.

Boolean search

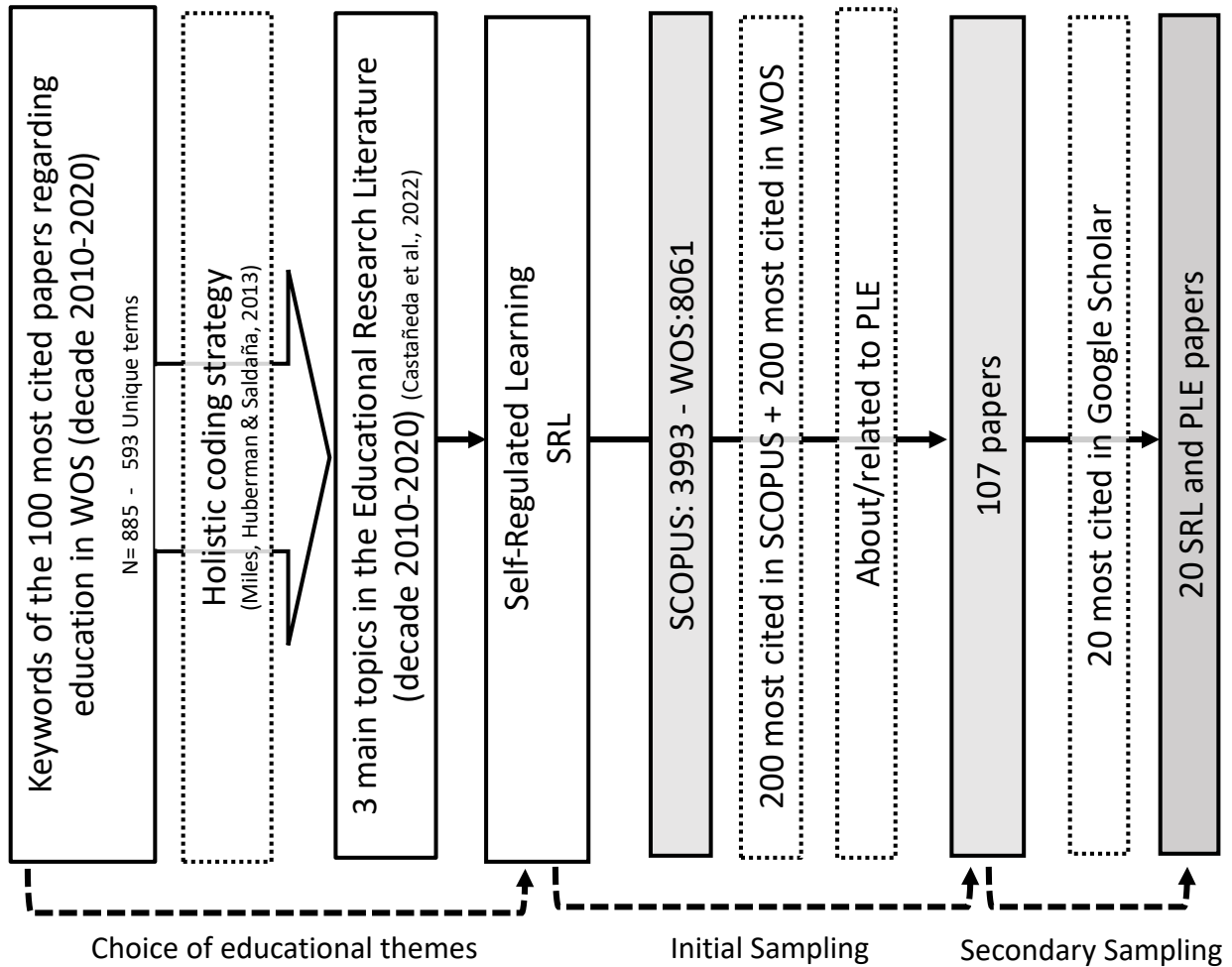| (TITLE-ABS-KEY (selfregulated OR self-regulated OR self-determined OR self-motivated OR self-regulation OR selfregulation OR auto-regulation OR auto-regulated OR autoregulation OR autoregulated)	AND TITLE-ABS-KEY (learning OR education OR training OR learners OR students))	AND DOCTYPE (ar) AND PUBYEAR > 2010 AND PUBYEAR < 2020 AND (LIMIT-TO (SUBJAREA , "SOCI"))

2.2.2 Sampling

After two of the research team members were trained in the search process, and the Boolean search chain was tested, the search was set in motion (see protocol in Figure 1). A double sampling process was carried out in order to guarantee a dual perspective (absolute and relative impact papers) in the analysis. The analysis is presented in the following section, although an overview of the sampling process can be seen in Figure 4 and the list of articles of each sample can be accessed here[1].

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[1] The entire lists of the sample process of the analysed articles is available at https://bit.ly/35Z9bsb (Tabs 4 and 7 for the two sample stages on PLEs and SRL)

Figure 4.

Sampling process

Keywords of the 100 most cited papers regarding education in WOS (decade 2010-2020)
N= 885 - 593 Unique terms

Holistic coding strategy (Miles, Huberman & Saldaña, 2013)

3 main topics in the Educational Research Literature (decade 2010-2020) (Castañeda et al., 2022)

Self-Regulated Learning SRL

SCOPUS: 3993 - WOS:8061

200 most cited in SCOPUS + 200 most cited in WOS

About/related to PLE

107 papers

20 most cited in Google Scholar

20 SRL and PLE papers

Choice of educational themes   Initial Sampling   Secondary Sampling

The initial sample includes the papers connected to the topic "personal learning environment" (meaning the inclusion of the term in the title, keywords or abstract), among the 200 most cited papers about SRL in both SCOPUS and WOS, published in the last decade and extracted from the database. As can be observed in Table 1, the 200 articles had received 5045 citations in Google Scholar at the time of the study, from which the vast majority (4233) were of the 20 most cited articles, which placed them among the most referenced SRL-related articles of the review period. It therefore appears that the impact of these articles that included both SRL and PLE is high in the field.

Table 1.

Summary of quantitative data

WOS- SCOPUS top SRL articles	200
WOS- SCOPUS top 200 SRL articles including PLE	6
Number of citations of the most cited SRL article including PLE in WOS & SCOPUS	1209
Number of citations of the least cited SRL article including PLE in WOS & SCOPUS	11
Year with the most published articles on PLE and SRL	2014 (6)
Cumulative Google Scholar citations of top 200 articles on PLE and SRL	5045
Cumulative Google Scholar citations of top 20 articles on PLE and SRL	4233

From all the papers related to SRL in WOS and SCOPUS in the last decade, those including the term "personal learning environment" in their title, keywords or abstract were selected. The selection of both databases was unified, and the duplicated papers were eliminated, resulting in 107 papers in total. Once unified and refined, the papers on SRL and PLE were classified according to their citations in Google Scholar and the 20 most cited were selected for a more profound analysis.

2.2.3 Coding

To analyze the sample, the author team proceeded with two rounds of coding: a first descriptive coding cycle (Saldaña, 2015) that identified the main characteristics of the papers including the relationship between SRL and PLE, followed by a second cycle of narrative coding that allowed us to carry out the meta-narrative approach, for which the aim is not to describe each paper in itself but rather the resulting picture of the research that features both concepts (Zawacki-Richter et al., 2020). After the coding, first cycle results were synthesized nominally, and the second cycle results were organized in a narrative manner.

3. Results
3.1 Analysis of general characteristics

Table 2.

Main characteristics of the top papers that show relationship between SRL and PLE

Top SRL & PLE Articles	20
Personal Learning Environment or PLE appears explicitly	10
PLE as central theme	6
PLE mixed approach	12
Empirical articles	16
If empirical, is it related to teaching and learning experiences?	10

As can be seen in Table 2, the relationship between SRL and PLE in these 20 articles is diverse. Ten articles from this collection mention the PLE concept explicitly, with six addressing PLE as a central theme of their work (see Appendix 1 and 2, where articles are ordered by number of citations in Google Scholar). Regarding how PLEs are defined in the articles, the vast majority of articles (12) approach PLEs from both and technological and educational perspectives, while eight have an educational focus, and none take a purely technological viewpoint (see Appendix 1 and 2). While there are four theoretical articles (Appendix 1), the other 16 are empirical studies (Appendix 2). Of the empirical studies, ten are based on teaching and learning experiences. The other six empirical pieces represent quantitative or qualitative studies based on surveys, interviews, or content analysis for general exploration of usages. There exists a diversity of educational contexts among the various studies (Appendix 2) including settings such as vocational training, higher education (undergraduate and graduate programs), primary and secondary education, and both online and blended learning. The duration of the studies also varies, ranging from a complete school year to shorter periods of 8 weeks.

3.2. Metanarrative Review: Features of the relationship between PLE and SRL

The qualitative analysis of the collection of 20 articles used a meta-narrative review approach (Zawacki-Richter et al., 2020). It resulted in a thematic narrative of 6 features which are represented synthetically in a concept map in Figure 5. This section describes how the 20 articles in this collection illustrate the main features of the impact of SRL on the evolution of the PLE concept in diverse ways: laying the foundations, offering models for interrelated work, extending the digital platforms with social networks, extending

learning activities with e-portfolios and other pedagogical strategies, and extending knowledge by carrying out further research on students' strategies or approaching them from new perspectives.

Figure 5.

SRL & PLE metanarrative review conceptual map.
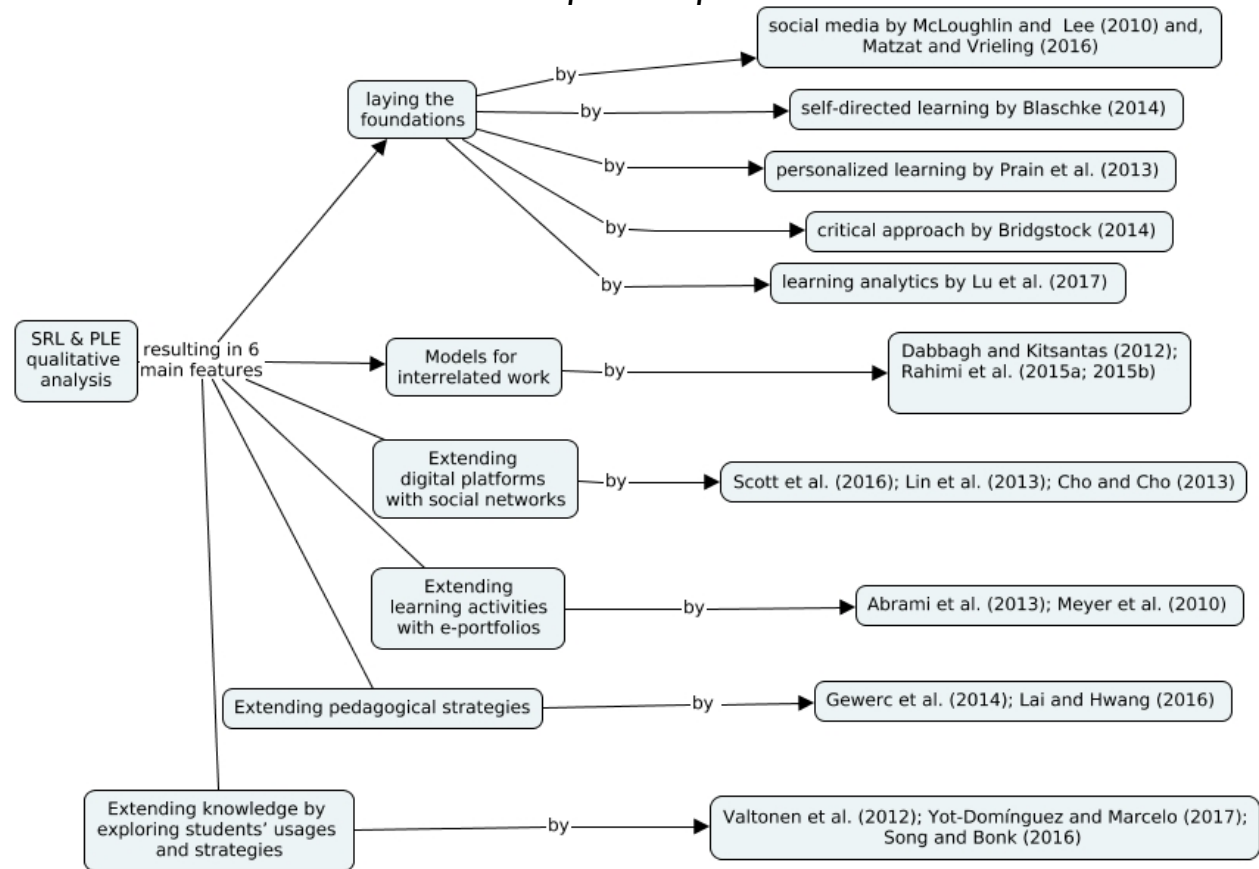
The results of the qualitative analysis are summarized in Table 3 with the main ideas of each of the features of the relationship between PLE and SRL.

Table 3.

Summary of the features of the PLE and SRL relationship

Feature	Summary
Laying the foundations	The foundations of the PLE and SRL relationship include social media as a natural alliance between the two concepts, and shared connections to achieving self-directed learning, allowing personalized learning, and potential improvement by learning analytics.

Feature	Summary
Offering models for interrelated work	The affordances of social media and other technologies used with PLEs may promote the diverse cognitive processes of each SRL phase.
Extending digital platforms with social networks	There is a prevalence of networking sites where students seem to develop SRL skills both in informal and formal learning and when being trained.
Extending learning activities with e-portfolios	Process eportfolios are highlighted as a suitable modality for SRL development, although the platforms developed by authors' teams seem to be online environments to support SRL skills rather than spaces for agentic activity.
Extending pedagogical strategies	Pedagogical strategies centered on PLEs and that are based on a collaborative approach or a flipped classroom design may develop SRL skills
Extending knowledge by exploring students' usages and strategies	Conclusions about students' usage support the idea that both digital skills and learning awareness are equally necessary for PLE development and that social support is a frequent SRL strategy observed in students working with PLE.

4.1. Laying the foundations

Six articles develop the foundational characteristics of the relationship between SRL and the PLE. One characteristic relates to social media and is represented by two articles. First, McLoughlin and Lee (2010) related Web 2.0 tools to the enhancement of the learner's autonomy and agency. Drawing on a review of the literature, the authors present an integrative approach to learning, called "self-regulated personalized learning" (p. 31), which they suggest is required in order to prevent the division of learning into multiple contexts. The authors stress the need for an explicit pedagogical design to ensure that technological tools are truly aimed at self-regulated learning. It is the first article presenting an initial discussion juxtaposing the role of Virtual Learning Environments (VLE) and PLE. VLEs are differentiated from PLE because VLEs are institutionally-centered and fail to optimize the social value of Web 2.0 due to their basis in traditional and conservative educational models.

Years later, the role of social media in linking PLE and SRL concepts achieved a new qualitative step forward with Matzat and Vrieling (2016), who describe the relationship between social media and self-regulated learning as a "natural alliance" (p. 73). In their study, results show that teachers who implement SRL strategies in their

lessons tend to make greater use of social media, although data collected does not demonstrate an intensive utilization, and there is a greater impact for metacognitive tasks corresponding to the performance phase. These authors show that some social media ally less naturally with SRL than others; for example teachers who predominantly use YouTube do not implement SRL strategies, and the reason why this is so – whether YouTube is more suitable for other educational purposes or whether teachers using YouTube may lack digital skills – remains unclear.

The work by Blaschke (2014) is another important contribution reflecting the progressive influence of metacognitive variables in the PLE concept's evolution. Although this is not the first time that self-directed learning has been related to PLE (see table 3 and 4 for other self-directed related articles), the central focus on heutagogy is innovative, and particularly relevant given that it is supported by empirical data. The author relates social media to self-directed learning and heutagogy "which places responsibility for the learning path in the hands of the learner" and emphasizes the learner's agency (Blaschke, 2014, p. 2-3). Thus, self-directed learning represents the development of lifelong learning skills, understood as a group of complementary characteristics and competencies that involve the ability to learn in complex situations.

Prain et al. (2013) contribute to laying the foundations with an article focused on the idea of personalized learning, which is based on the concepts of SRL and agency along with a differentiated development of the school curriculum, within hybrid contexts that include both formal settings and informal scenarios along with online environments. The "framework for conceptualising and enacting personalised learning" (p. 661) developed by the authors suggests that it requires team teachers "enacting and evaluating a differentiated curriculum" (p. 672), enabling "relational agency" among teachers and students while at the same time supporting personalized learning.

The only critical approach is taken by Bridgstock (2014), who suggests that higher education does not necessarily lead to professional learning for those devoted to digital careers, while on the other hand, more situated online and face-to-face learning might have a greater impact. Based on these conclusions, Bridgstock (2014) suggests that higher education should be understood as "hubs of the distributed knowledge network" (p. 9) for informal and self-determined pedagogical experiences along with communities of practice where situated learning occurs.

Lu et al. (2017) describe how the use of learning analytics in a MOOC impacted student engagement and SRL skill development. This study demonstrates that applying learning analytics improved students' engagement and increased the use of SRL strategies in contrast to students participating in the control group. Learning analytics implemented in a computer-assisted learning activity can help identify students at risk and support teachers in adapting their pedagogical designs to these students' needs.

4.2. Models for interrelated work

Additional features in the conceptual evolution of PLE and their interrelation with SRL are described in two rich theoretical articles by Dabbagh and Kitsantas (2012) and Rahimi et al. (2015a). The former presents an educational model displaying the complementary role of the three stages of Zimmerman's (2000) self-regulation cycle (forethought, performance, and self-evaluation) and the three levels of social media usage (personal information management, social interaction and collaboration, and aggregation and information management). The aim of the model is to offer teachers a framework for the progressive introduction of social media for PLE construction and the enhancement of self-regulated learning. The authors' understanding of the relationship between PLE and SRL is that the two concepts are "interdependent and synergistic" (Dabbagh & Kitsantas, 2012, p.5), and is based on their own previous work, where they observed that social media can promote students' SRL when constructing their PLE.

Rahimi et al. (2015a) design a complex model in which many variables play different parts. The variables include students' control dimensions (capability, support, and autonomy); learning affordances of Web 2.0 tools; technology enhanced learning activities; the student-driven PLE construction process; and the SRL process defined by Zimmerman's (2000) three phases and a fourth called *feeding back* (applying). These variables combine to lead to an increased control on the part of learners, who are also influenced by their own abilities and their communication with teachers. This theoretical model was implemented and validated by secondary education students in the Netherlands, and the resulting study, which is included in the collection of top articles (Rahimi et al., 2015b), contributes by showing the impact of communication between students and teachers to promote engagement for the construction of students' digital environments.

Kitsantas (2013) on her own also adds a model for the development of SRL skills through what she calls "learning technologies," among which social networking services play an important role, and for which she observes four phases of learning (Zimmerman, 2000): observation, emulation, self-control, and self-regulation. However, there is an aspect of this work that leads us to consider the distinctive nature of PLE. In Kitsantas's list of examples of learning technologies and instructional designs aligned with SRL skills, she includes both social media and other tools included in VLE. To do so, she argues that previous research demonstrated the manner whereby VLE tools for organization, content creation, and distribution are useful for diverse SRL processes. It is suggested that for the success of SRL skill development, learning design is a key element, as is awareness of not focusing on aims and outcomes too prematurely. Moreover, there is a range of possibilities in learning technologies to

connect with students' preferred choices, which would enhance students' motivation, a key factor in self-regulation of learning.

4.3. Extending digital platforms with social networks

Among the 20 articles in the second sample, a particular focus on social networking platforms, students' activities, and the related learning design stands out. Three articles in the collection address the relationship between SRL and social networks (Scott et al., 2016; Lin et al., 2013; Cho & Cho, 2013), among which one (Lin et al., 2013) mentions PLEs as part of the general framework in which students' social networking is embedded. Scott et al. (2016) analyze student activities with diverse types of social media, and they observe students' practice of SRL skills in these social spaces for informal learning. Cho and Cho (2013) observe how students who were first trained in SRL skills used Twitter to plan and reflect more frequently than students in the control group. Also, students in the experimental group supported each other more frequently, by offering both academic and emotional support. Lin et al. (2013) demonstrate that students with high-centrality in social networks and with low SRL skills can improve their metacognitive skills due to their exposure to peers' interaction and support.

4.4. Extending learning activities with e-portfolios

Special mention should be made of e-portfolios as a teaching and learning strategy clearly related to both PLE and SRL. This relationship can be observed from the two articles included in this collection that are on e-portfolio implementation in diverse formal educational contexts (Abrami et al., 2013; Meyer et al., 2010). In Abrami et al. (2013), SRL underpins their e-portfolio environment. However, their e-portfolio environment emerges as a system to scaffold students by supporting each step of their learning process and still seems a long way from learners exercising true control and ownership of their learning. In the work developed with the ePEARL software by the two teams of Abrami et al. (2013) and Meyer et al. (2010), process e-portfolios are conceived as the best modality, although not the only one, to enhance SRL, and are defined as "personal management tools" (Meyer et al. 2010, p. 85; Abrami et al., 2013, p. 1189). They describe these tools as supporting reflection, among other SRL skills, and also abilities and literacy skills.

4.5. Extending pedagogical strategies

There are two articles in this collection that address metacognitive learning through digital environments with specific pedagogical strategies (Gewerc et al., 2014; Lai & Hwang, 2016). Gewerc, Montero and Lama (2014) analyze student teachers' social activity from a networking approach in order to observe collaborative strategies

enhanced by the learning design implemented. Data collected showed that there existed a dominant node of students with higher interactive activity but also during the course it could be seen how collaboration was distributed among students, and how teachers could focus on interactions with those who needed greater scaffolding. Lai and Hwang (2016) explored a flipped classroom approach in mathematics instruction for elementary students to foster SRL skills. Results show that students who participated in the self-regulated flipped classroom approach showed higher levels of self-efficacy skills while improving strategies for planning, setting goals and using study time, which can in turn lead to better learning outcomes. The authors suggest that a flipped classroom approach without the focus of SRL may not have the hoped for results.

4.6. Extending knowledge by exploring students' usages and strategies

Three articles could be grouped together and described as having extended the knowledge about particular utilizations and learning strategies by students, with one of them developed with PLE as the main conceptual framework (Valtonen et al., 2012). In the case of the work by Valtonen et al. (2012) PLEs belonging to vocational students are seen to have been built as conventional learning environments, and as a space to demonstrate outcomes, to reflect on learning, and to collaborate with others. The authors conclude that developing one's own PLE is a demanding activity that requires both digital skills and learning awareness. Yot-Domínguez and Marcelo (2017) explore the usage of digital tools in terms of SRL and the main conclusion is that higher education students tend not to use these tools to self-regulate their learning. It can be observed that access to information and instant communication is the most frequent activity with digital tools whereas social support is the most frequent SRL strategy observed in students. Song and Bonk (2016) explore the motivational factors of self-directed learning in digital environments and concluded that the main triggers which are both motivations and key factors are "freedom and choice, control, interest and engagement" (p. 9).

5.   Discussion

In this article, the relationship between PLE and SRL has been explored, and the literature reviewed suggests that SRL and PLE are two related concepts that have been mutually influenced by each other's development. Based on the review of the 20 articles included in WOS and Scopus databases with the greatest number of citations in Google Scholar, the PLE concept has underscored how digital environments can highlight a greater, multifaceted understanding of cognitive skills associated with learning in a digital era. In the EdTech field, SRL has been integrated as a concept that helps to overcome a purely technological and content-based understanding of PLE, and has helped defined PLE evolution over the last decade.

SRL is intrinsically a part of the educational and educational-technological understandings of the PLE concept, although not always in a clear way. In general, it has been shown that PLE are understood as contexts that allow for the development of the metacognitive strategies of the SRL model. In this regard, the use of e-portfolio-based learning environments to enhance reflection (see Roberts, 2018) may become an important practice to explore in further research as the catalyst for self-directed learning that goes beyond the use of SRL skills in formal contexts. However, teachers may focus on the instrumental side of PLE, which has the aim of scaffolding planning, performance, and reflection related to learning. It appears there is something more in PLE that can distinguish them from other digital environments that could be related to self-directed learning. Johnson and Liber (2008) addressed this issue at the dawn of PLE research when they highlighted the transformation of the learning nature in digital environments and its consequences for learner autonomy. Eventually, the self-directed model can potentially have a direct impact on learners' agency, and empower them to take control and ownership of their own learning processes in all formal and informal learning contexts throughout their whole life, not solely in the performance of academic tasks.

The variety of educational contexts in the reviewed literature suggests that the relationship between PLE and SRL is relevant to consideration of education at various levels, from elementary education to post-compulsory education, and in diverse contexts, from totally distant online learning to blended learning. In the literature, the length of the learning activities that were explored is diverse, but based on a recommendation by Rahimi, van den Berg, and Veen (2015b) it seems that for the true development of SRL skills, longer periods would be more advisable than shorter designs.

Considering the features of the reviewed literature helps identify gaps in the knowledge base. First of all, SRL may be influenced by personal variables such as gender, age, fields of knowledge, or cultural backgrounds (Zimmerman, 2000). Likewise, the EdTech field has observed the influence of such variables, particularly in the Science, Technology, Engineering, and Maths (STEM) fields (Wong & Kemp, 2017). However, prior research that has addressed both SRL and PLE has not seemed to consider such variables as relevant to include either in research or educational design and future research could advance the knowledge base by attending to learner characteristics. Secondly, the SRL concept is also concerned with the social context in which these personal strategies are developed (Zimmerman, 2000), and the social implications of PLE seem to perfectly fit into this mandate. Thus, it could be argued that a valuable addition to the literature would be research that addresses this noticeable gap and explores the social components of SRL processes (Isohätälä et al., 2017) in PLE settings. Thirdly, SRL and PLE concepts both relate to a third concept, digital

literacy, that is critically important in contemporary education (Muthupoltotage & Gardner, 2018) and that also highlights potential linkages to other current topics that include privacy issues (Marín et al., 2021) and personal data literacies (Selwyn & Pangrazio, 2018) .

Many lessons can be learned from the design of learning informed by both SRL and PLE concepts but we should also consider that the importance of the interconnection of these two critical educational themes lies in their potential to improve educational practice and student learning. This means not only enriching what has been done so far, but also exploring the possibilities of what have been called emergent pedagogies (Veletsianos, 2016). Thus, based on the lessons learned in the literature review presented above, we offer recommendations for future work, both for educational implementation and related research:

- Extend the contexts and periods of SRL and PLE learning tasks towards global programs that involve all levels of education and all content areas;
- Investigate explicit scaffolding of SRL that is included in different PLE models, including data-driven platforms, and the impact of that scaffolding on PLE outcomes;
- Explore metacognitive processes in PLE development and the nuances that may arise depending on elements of the learning designs;
- Consider e-portfolio-based learning environments to enhance reflective and self-directed learning aims beyond SRL in formal contexts;
- Extend the analysis of SRL processes in PLE settings from critical approaches such as gender, cultural background, and data literacies while taking care of privacy issues; and
- Explore the social aspects of SRL to better inform and develop the social process involved in PLE development.

6.   Conclusion

That only 6 of the 200 most cited papers on SRL reference PLE might suggest a limited relationship between SRL and PLE. However, consideration of a selection of the articles that included both SRL and PLE suggests a deep impact that has defined the features of their relationship.

In recent years, there has been a growing interest in the "personal" characteristic of virtual learning environments (Author et al., 2018; García-Martínez et a., 2020) and, recently, the development of adaptative digital environments has meant that the term "personal" is understood in relation to a system that is adapted to students' needs based on the data they have generated. However, consideration of the PLE and SRL concepts together highlights that this is not what "personal" means in the PLE approach (Attwell, 2021; Pedro & Santos, 2021); "personal" instead refers to students' control

and ownership over both tools and processes for learning. In an era when education is very much influenced by current neoliberal trends and when in some cases educational technology businesses align with governmental institutions for the control of education and the usage of students' personal data for their own profit (Kühn, 2019), it is important to clarify that PLE can be tied to the development of SRL that empowers students as critical and autonomous lifelong learners (Castañeda et al., in press; Perifanou & Economides, 2021). As this study has highlighted, when considered together, PLE and SRL are not inevitably wed to an individualistic view of education, and are far from any automatic or predictable way of thinking as to the manner in which people learn. On the contrary, these two concepts can be central constructs of an approach to education that highlights the emancipating role of learning from a social and personal viewpoint (Calatayud & Gutierrez, 2018; Dabbagh & Castañeda, 2020; García-Martínez & Gonzalez-Sanmamed, 2020; Lim & Newby, 2021). PLEs with their design aligned with SRL may offer one of the most suitable ways to prepare students in the years to come, managing existing challenges but also the new ones created by the COVID-19 pandemic and the need for autonomy for sustainable online learning (Adedoyin & Soykan, 2020; Attwell, 2019; Castañeda & Tur, 2020; Chen et al., 2021; Dabbagh & Castañeda, 2020; Karatas & Arpaci, 2021).

This study addresses the knowledge gap about how PLE and SLR have been interrelated during the last decade of research and evidences interest in educational research and practice in the approaches that incorporate both concepts in different contexts. That PLE development requires metacognitive skills has been long argued; that the COVID pandemic has demonstrated that those with SRL skills have been more successful for online learning has been more recently claimed. The panoramic overview of the research on SRL and PLE undertaken in this work is an effort to uncover the characteristics of this close relationship in a detailed way. The six features of research identified also help define the need for further work in under-researched areas and delineate areas that have received attention but would benefit from further exploration as well.

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APPENDIX 1

Table. Theoretical articles with a central focus on PLE, SRL, and related concepts

Reference	Psychological/ educational concept	PLE concept & approach	Conceptual interrelationship	Main recommendation(s)
Dabbagh & Kitsantas (2012)	SRL	PLE Educational	"Specifically, PLEs require the development and application of self-regulated learning skills because PLEs are built bottom-up starting with personal goals, information management, and individual knowledge construction, and progressing to socially mediated knowledge and networked learning" (pp. 4-5)	In research, explore social media use through the levels of the authors' model and explore how SRL skills impact on students' PLE
McLoughlin & Lee (2010)	SRL Self-directed	PLE Educational	"Of late, the personal learning environment (PLE) has emerged as a concept associated with the adoption of a raft of Web 2.0 tools that serves to integrate essential learning outcomes such as lifelong learning, informal learning and self directed learning" (p. 29)	Improve scaffolding of fundamental skills and digital literacy, and attention to privacy issues
Rahimi & Van Den Berg & Veen (2015a)	SRL Self-directed	PLE Educational	"It can be argued that any model that aims to support student's control by developing and applying Web 2.0 PLEs should (1) improve the student's	Developing skills in social media is a long-term interactive process between students and teachers.

			cognitive and metacognitive abilities and redefine his or her epistemic practices (…) (4) take advantage of the learning affordances of Web 2.0 tools and technologies to design appropriate technology-enhanced teaching and learning activities and provide opportunities for the student to make decisions about his or her learning activities." (p. 3)	Need to implement the model in diverse scenarios
Kitsantas (2013)	SRL	Learning technologies Mixed	"A growing body of research shows that learning technologies can engage learners in self-regulated cycles of learning (P. 238)"	It is important not only to design environments for SRL but also to offer students' the opportunity to choose, which in turn can benefit their motivation.

APPENDIX 2

Table. Empirical articles with a central focus on PLE, SRL, and related concepts

Reference	Psychological/educational concept	PLE concept & approach	Conceptual interrelationship	Empirical study & Learning activity context	Impact
Lai C.-L., Hwang G.-J. (2016)	SRL	Interactive learning environments Mixed	"Self-regulated learning system was developed for supporting the flipped classroom	Experimental and control group.	Integrating SRL into flipped classroom can improve

			learning activities" (p. 7)	Elementary school Mathematics course	students' self-efficacy and strategies of planning and study time
Meyer, Abrami, Wade, Aslan & Deault (2010)	SRL	Web-based electronic portfolio (PLE mention) Mixed	"(…)process eportfolios are linked to students' abilities to self-regulate their learning and to enhance their development of important educational skills and abilities, especially literacy skills. " (p. 85)	Learning activity One school year, Non-university levels	Increasing ICT and literacy skills, motivational and cognitive benefits
Valtonen T., Hacklin S., Dillon P., Vesisenaho M., Kukkonen J., Hietanen A.(2012)	SRL Self-directed learning	PLE Mixed	"PLEs are typically described as a collection of different ICT tools and software, usually social software, to foster self-regulated and collaborative learning" (p. 732)	Learning activity One school year Vocational and polytechnic levels	PLEs for mirroring LMS, reflecting, showcasing skills, and for collaborating and networking (p. 732)
Blaschke (2014)	Self-directed	Social media (PLE mention) Mixed	"One approach is to encourage students to use social media actively in their learning and research, opening	Learning activity Online master's degree, during six semesters	Engage learners in active learning, support and extend learning

			up the potential for them to develop the skills they need for creating a personal learning environment (PLE) and bringing them a step closer toward becoming more self-directed learners" (p.1)	from 2012 to 2013	
Prain V., Cox P., Deed C., Dorman J., Edwards D., Farrelly C., Keeffe M., Lovejoy V., Mow L., Sellings P., Waldrip B., Yager Z. (2013)	Self-regulated learning	Personalised learning environment (diferentiated curriculum) Educational	"Student personalized learning experience. Integration of differentiation self-regulation strategies by individual students" (p.661)	Learning activity Four secondary schools Australia	"Personalised learning depends on the expertise of teachers to support students' meaningful goal-setting, and the provision of an engaging curriculum" (p. 672)
Scott K.S., Sorokti K.H., Merrell J.D. (2016)	SRL	Enterprise social. Network system (PLE mention) MIxed	"Some of what happens in these spaces can be purely social, such as sharing photos of weddings, babies or pets,	Content analysis from non-compulsory ESN usage by students of a	Majority of students who used ESN. High levels of cognitive and learning presence

			while other activity can be classified as self-regulated learning, such as asking for help with a professional project or sharing a point-of-view about a topic of interest with the community" (p. 78)	graduate program	
Lin J.-W., Huang H.-H., Chuang Y.-S. (2015)	SRL	e-learning environment Mixed	"It is known that network centrality profoundly impacts student learning in an SNA e-learning environment. Meanwhile, self-regulation behavior also profoundly impacts student online learning.(…) However, exactly how network centrality and self-regulation influence learning behavior and effectiveness in an SNA e-learning environment remains contentious " (p. 34)	Survey Experimental procedure University	The student group with high-level centrality and low-level self-regulation more significantly progresses in learning achievement than the other groups. The second finding shows the group also has the highest number of students asking for help, revealing they have the highest system utilization rate.

Rahimi & Van Den Berg & Veen (2015b)	SRL Self-directed	PLE Educational	"This student-driven approach to personalizing learning and constructing learning environment has been suggested as a necessity to (…) and develop self-regulated learning competencies among students " (p. 235)	Learning activity Secondary education, 8-week activity	Students' engagement
Lu O.H.T., Huang J.C.H., Huang A.Y.Q., Yang S.J.H. (2017)	SRL	MOOC (PLE mention) Mixed	"They showed that a personal learning environment with a learning analytics approach provided positive effects on students' learning performance" (p. 2)	Learning activity 10 weeks University	Results show improvement of engagement and outcomes of students who could self-regulate their processes with learning analytics
Abrami, Venkatesh, Meyer & Wade (2013)	SRL	Computer-based system (e-portfolio) Mixed	Process EPs are linked to students' abilities to self-regulate their learning and to enhance their development of important educational skills and abilities,	Learning activity Primary Education participants: students and teachers, during a school year.	Positive impact on SRL and literacy skills

			especially literacy skills (p. 1190)		
Bridgstock R. (2016)	Self-determined learning	Digital media Mixed	"universities are now tasked with hard-to-teach high-level twenty-first century meta-capabilities such as self-regulation of learning, knowledge construction and synthesis, creativity, adaptability, information management, critical thinking and digital competence (Plomp, 2013), along with professional-level disciplinary skills for the information society" (p.1)	Empirical study Interviews with digital media professionals	Learning related to informal, self-determined learning and communities of practice (p. 1)
Gewerc A., Montero L., Lama M. (2014)	Independent learning SRL	Social networking PLE Educational	"This innovation is based on the premise of student-centered teaching (independent learning, self-regulated, authentic and breaking boundaries between formal and informal areas)	Learning activity Teacher education program One semester	Among diverse results, analysis show "that the content elaborated by students has a high level of relevance. This is

			enriched with collaborative activities" (p. 55)		extremely interesting given the freedom to delve into the theoretical and practical topics studied in class, which is an indicator of self-regulated learning skills" (p. 61)
Matzat U., Vrieling E.M. (2016)	Self-regulated learning	Social media Educational		Empirical study Survey	Teachers who practice SRL in the classroom, are more inclined to use social media (p. 73)
Song D., Bonk C.J. (2016)	Self-directed learning Self-determined learning	Online learning Educational	"Learning is becoming increasingly self-directed, open, and informal (Bonk, 2009, 2010). Learners have increasing choice over the timing, location, contents, and path of their learning. As such, it is vital to examine their learning goals, obstacles, and successes when	Survey among learners from learning websites	Results show that there are three aspects in motivation for self-directed learning: freedom and choice, control, interest and engagement (p. 9 of 11)

			accessing open online content in an informal manner" (p.2)		
Cho K., Cho M.-H. (2013)	SRL	Social network system (Twitter) Mixed	How SRL skills were applied in their learning setting after the training by analyzing tweets	Undergraduate students One semester	Students in the experimental group used more SRL skills such as planning and reflecting
Yot-Domínguez C., Marcelo C. (2017)	SRL	Digital technologies Mixed	"Developing this self-regulation cycle could be facilitated by technologies" (p.3)	Empirical survey	The most generalized SRL strategies are those relative to social support