The Synergy of Educational Technologies and Self-Regulated Learning: A Systematic Scoping Literature Review

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Abstract. The rapid advancement of artificial intelligence (AI) technology necessitates addressing the topic of self-regulated learning (SRL) given its potential for personalized learning experiences. Educational Technologies (EdTech) have the capacity to facilitate SRL within educational contexts, particularly in remote learning scenarios. This study explores the interplay between EdTech and SRL, highlighting their synergistic relationship. Through a systematic scoping literature review following the methodology of Peters et al., evidence from 328 records in the Scopus database was synthesized, with an analysis of 112 reports meeting the inclusion criteria published between January 2015 and February 2024. Zimmerman's cyclical phases model emerged as the predominant SRL framework in connection with EdTech. Additionally, the identified EdTechs were categorized into eleven clusters based on shared characteristics and mapped onto Zimmerman's SRL model to create an EdTech-SRL-Synergy-Map. Recommendations are made for future research, particularly in the secondary education sector, and the significance of SRL practices in an educational landscape permeated by AI is emphasized.

Keywords: Educational Technology, Self-regulated Learning, Systematic Scoping Literature Review

1 Introduction

With rapid progress in artificial intelligence (AI) technology, we anticipate that addressing the subject of self-regulated learning (SRL) is imperative. The customization of learning materials with AI holds the potential to usher in a promising era in which learners can engage in a profoundly personalized learning experience. Over the last four decades, SRL has become an important topic in

educational psychology. According to Beishuizen and Steffens [10], the reason for this is due to the fact that we live in societies in which lifelong learning is becoming increasingly important and it is desirable to be able to improve these skills in learners. Additionally, according to Panadero [51], the current advances in the field of SRL signal that its relevance will continue.

Various models have been created to describe the SRL processes. Panadero's review of self-regulated learning [51] identified Zimmerman's cyclical phases model, Boekaerts' dual processing model, and models from Winne and Hadwin, Pintrich, Efklides, and Hadwin, Järvelä, and Miller. These models are advantageous for understanding the effects of interventions in different educational settings and demographics. In the scoping review by Urbina et al. [63], Zimmerman's cyclical model from 2000 and its later revisions were mentioned most often in the included reports. According to Urbina et al., this model shows great explanatory power and has been the predominant model in research in the field of education when working with teachers. The SRL model proposed by Zimmerman [71] describes self-regulation in three phases: forethought, performance, and self-reflection. Zimmerman concluded, that *students' use of high-quality SRL processes can enhance their motivation to continue additional cycles of learning.*

Furthermore, because *SRL involves a dynamic feedback loop* [71], Educational Technologies (EdTech) are gaining attention. Bartolomé and Steffens [8] assert that advancements in technology enable the creation of learning environments enriched with technology, offering substantial potential for fostering SRL. Broadbent and Poon [12] emphasized the necessity of comprehending how students can optimally utilize SRL strategies to achieve academic success, considering the rapid expansion of online learning over the past decade. Additionally, educators should not assume that online learning itself fosters the use or development of SRL strategies, however, SRL skills are required in distance education settings [12,43]. Educators should take advantage of digital platforms such as flexibility and accessibility while simultaneously fostering the growth of self-control abilities [12]. The synergy between EdTech and SRL generates compelling dynamics from our perspective. However, which EdTech is suitable for fostering SRL skills and what are its strengths and weaknesses?

Bringing all this together, the question arises if there is an SRL model that is predominant in current EdTech research and which EdTech is investigated to foster SRL. To synthesize the research evidence in this heterogeneous literature, this systematic scoping literature review in accordance with the methodology of Peters et al. [52] was conducted. The following review questions (RQ) guide this study:

RQ1: Which SRL model is applied primarily in EdTech research?
RQ2: Which EdTechs are currently in the focus of research to support SRL?

2   Method

To address these broad review questions, this review followed the methodology paper from Peters et al. for systematic scoping literature reviews [52]. The in-

clusion and exclusion criteria are listed in Table 1. As this study explores where SRL is being researched in an educational context, no limitations on the types of participants (e.g. school- or university-students, professional development) were defined. In order to focus on more recent research findings, only studies from the last decade have been included. To ensure transparency and acknowledging the original authors, it is imperative that the authors are named.

Table 1. Inclusion- and Exclusion-Criteria for this Scoping Review

aspect	inclusion criteria	exclusion criteria
publication date	between 2015 and 2024	before 2015 or after 2024 or NO date given
language	English or German	other than English or German
EdTech	EdTech used	NO EdTech was used
SRL	SRL linked to EdTech	SRL NOT linked to EdTech
authors	authors are named	authors are NOT named

The search strategy was designed to create a comprehensive overview of the research conducted over the last nine years. Therefore the keywords *"educational AND technology AND self-regulated AND learning"* were used in the search fields *title, abstract, keywords* on the database Scopus.com, resulting in 328 records for the time-frame 2015 to 2024 (last search on February 26th, 2024). All titles and abstracts were screened and the inclusion and exclusion criteria were applied; 257 records remained for document retrieval. During retrieval, 24 documents could not be retrieved, 11 documents had a language different from English and German, and 3 records were identified as duplicates. For the full-text analysis of the 219 reports eleven extraction fields were defined, see Figure 1.

During the full-text analysis, 107 documents were excluded: In 41 reports SRL was not related to EdTech, in 35 reports no SRL model was mentioned, in 16 reports no EdTech was used, and 15 reports were overview articles. Information from each record relevant to the extraction fields was collected on a spreadsheet. The authors crosschecked the extraction process and achieved a compliance rate of over 85%. A visualization of the literature review process adapted from the PRISMA statement [49] is shown in Figure 2. The results are described and visualized in the next section.

3   Results

This review included 112 journal articles (n=85), conference proceedings (n=19), and book sections (n=8). We call these research items further *reports* according to PRISMA [49]. A complete list of all references of the included reports is available at https://doi.org/10.3217/cbp57-0a514
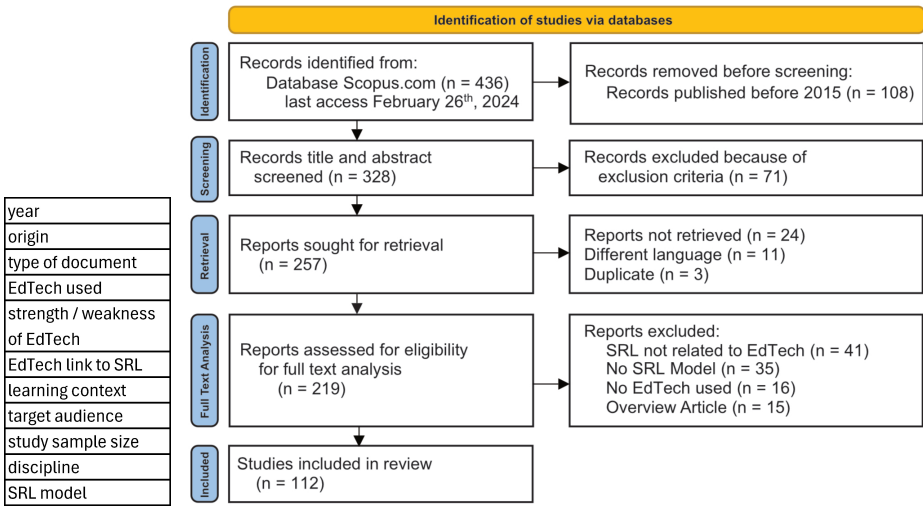
Identification of studies via databases

Identification

Records identified from:
Database Scopus.com (n = 436)
last access February 26th, 2024

→ Records removed before screening:
Records published before 2015 (n = 108)

Screening

Records title and abstract
screened (n = 328)

→ Records excluded because of
exclusion criteria (n = 71)

Retrieval

Reports sought for retrieval
(n = 257)

→ Reports not retrieved (n = 24)
Different language (n = 11)
Duplicate (n = 3)

Full Text Analysis

Reports assessed for eligibility
for full text analysis
(n = 219)

→ Reports excluded:
SRL not related to EdTech (n = 41)
No SRL Model (n = 35)
No EdTech used (n = 16)
Overview Article (n = 15)

Included

Studies included in review
(n = 112)

year
origin
type of document
EdTech used
strength / weakness of EdTech
EdTech link to SRL
learning context
target audience
study sample size
discipline
SRL model

Fig. 1. Extraction Fields

Fig. 2. PRISMA Flow Diagram Showing Systematic Literature Review Process, Adapted from [49].

The included reports originated from 36 countries. The countries most frequently included in this review are the USA (n=20), Australia (n=10), and Spain (n=10). The reports were published between 2015 and 2024, see Figure 3, with more reports published in recent years.

The target audience of the intervention was mentioned in 77 reports. Most reports researched university students (some reports further specified undergraduate-, graduate- and college-students, all subsumed under university students). With elementary, middle, and high schools summarized, 22.5 % of the reports researched primary and secondary education, see Figure 4.
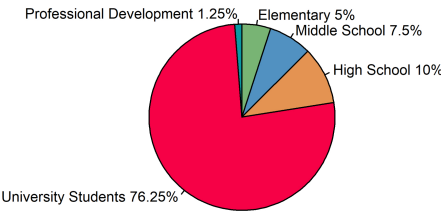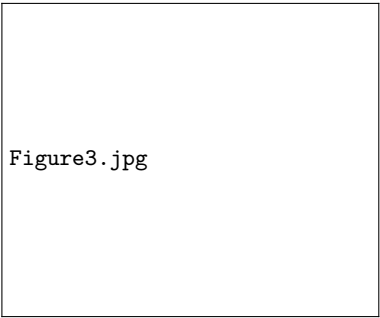
Figure3.jpg

Professional Development 1.25%
Elementary 5%
Middle School 7.5%
High School 10%
University Students 76.25%

Fig. 3. Publication Year of the Included 112 Reports

Fig. 4. Target Audience of the Intervention, Mentioned in 77 Reports

The number of participants in the study was mentioned in 74 reports, with a median of 124 participants. This visualization is shown in Figure 5. The disciplines in which EdTechs were applied in relation to SRL ranged widely. 59 reports mentioned a discipline, with both English as a Foreign Language (EFL, n=11) and Computer Sciences (CS, n=10) named most frequently, see Figure 6.

Different SRL models are mentioned in the reports, and multiple models are referenced partly in the same report. Zimmerman (n=85) was mentioned the most often, followed by Pintrich (n=32), see Figure 7.

Fig. 5. Box Plot of Number of Participants in 74 Reports. (Q1: 60, Q2: 124, Q3: 227)

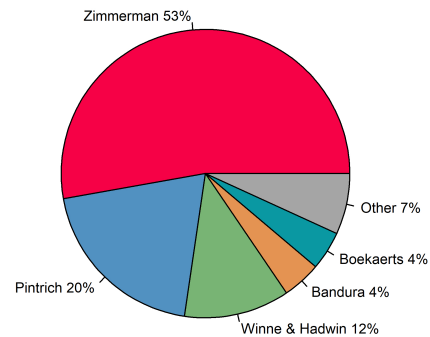**Fig. 6.** Disciplines Mentioned in 59 Reports

Fig. 7. SRL Models Mentioned in the Included Reports (Partly Mentioned Multiple Times)

Various learning contexts have been described in the reports. These are (with a representative reference): Traditional classroom contexts [57], university courses [33], instructor-focused [1], and laboratory-based studies [26] and more EdTech focused contexts such as adaptive learning environments [23], blended learning [47], flipped classrooms [28], game-based learning [66], distance learning [15], nanolearning [53], and online learning [21]. Other modern learning contexts that focus on students, such as agile education [62] and problem-based learning (PBL) [6], are described as well.

3.1   EdTech in Reports

To provide an overview of the EdTechs studied in the 112 included reports, eleven clusters with common characteristics emerged after the extraction process. Some

EdTechs can be included in several clusters, however, they are included only in the best-fitting cluster. Several reports have investigated the same EdTech, but only one outstanding reference is cited.

Reports since 2015 described **educational resources linked to technology** (n=23) like massive open online courses (MOOC) [28], open educational resources (OER) [29], online tools [20], videos [53], and hardware like tablets [37]; **learning analytics (LA)** (n=17) with educational data minding (EDM) [45], eye-tracking technologies [33], learning analytics dashboards (LAD) [32], gamified LAD [25], LA [41] and multimodal LA [18]; **personalized EdTech** (n=11) like intelligent tutoring systems (ITS) [5], personalized EdTech [22], personalized scaffolds [38], personalized learning environments (PLE) [40]; since 2016 **digital learning environments** (n=30) like adaptive environments [4], systems for blended or online courses [69], online learning [67], support systems [17], environments for flipped classrooms [42], interactive-environments [64], -materials [36], and -modules [57]; learning management software (LMS), such as Blackboard [3] and Moodle [48], quizzes in LMS [58], LMS for SRL[31]; **immersive technology** (n=5) like augmented reality (AR) [27], virtual laboratories [54], virtual reality (VR) [59], and game-based VR [16]; **mobile learning** (n=6) like mobile assisted language learning [30], mobile application learning [60], and mobile ePortfolios [35]; since 2017 **collaborative technology** (n=3) including tools for project workflow (Kanban Boards) [62] and social support systems [68]; **gaming technology** (n=6) like educational games [44], game-based environments [65], and serious games [56]; since 2018 **feedback tools** (n=2) like audience response systems (ARS) [11] and feedback tools for academic writing [70]; since 2019 **ePortfolios** [2] (n=3) and since 2023 **artificial intelligence (AI)** (n=6) like chatbots [14], generative AI (e.g. ChatGPT) [39], and AI assistants [19].

4   Discussion

4.1   SRL Model

To address **RQ1**, *Which SRL model is applied primarily in EdTech research?*, the extraction process revealed that Zimmerman's cyclical phases model [71] was predominant, as shown in Figure 7. In accordance with other studies such as the scoping review by Urbina et al. [63], which focused only on technology enhanced learning environments, the same SRL models were mentioned most frequently. The model from Zimmerman [71], however, is mentioned more often according to our review (53 % compared to 35.2 %). Therefore, this review focuses on Zimmerman's SRL model.

Different **SRL Instruments** (standardized methods to investigate the effects of EdTech on SRL) were used in the included reports, which are either directly relating to or adapting the SRL model from Zimmerman: To examine online learning self-efficacy, the *Online Learning Self-Efficacy Scale (OLSES)* [72] was used in [61]. The *Online Self-Regulated Learning Questionnaire (OSLQ)* by Barnard et al. [7] was used in [25], for MOOCs, the *MOOC Online Self-Regulated Learning Questionnaire (MOSLQ)* was created by Onah et al. [47] based on the

OSLQ. The *SelfReg Questionnaire*, developed by Rizzo et al. [55], was used in [44]. The *Adaptive Self-regulated Learning Questionnaire (ASRQ)* [24] was used by Harati et al. [23].

4.2   Different EdTechs used to promote SRL

To address **RQ2**, *Which EdTechs are currently in the focus of research to support SRL?*, we discuss the possibilities of different EdTechs mentioned in the reports. The following are the strengths and weaknesses of the eleven clusters that emerged during the extraction process to support SRL:

AI can support SRL during each phase from Zimmerman's SRL model. Chatbots can help set goals, task strategies, and create self-evaluation questions in a highly personalized manner [14]. One outcome from Darvishi et al. [19], however, was that the students tended to rely on, rather than learn from, AI assistance.

Collaborative Technology can support SRL during the forethought phase using kanban boards for strategic planning [62]

Digital Learning Environments can support SRL during every phase [17]. They provide flexibility and fewer spatial and time restrictions, which leads to ownership of their own learning process and require SRL strategies [69]. Adaptive technology requires independent learners with high SRL skills [23] and SRL strategies are required in online learning environments [13]. According to Moos and Stewart [42], teachers should provide explicit goals so that students can effectively self-regulate their learning in subsequent activities. Faculty members should be aware of the importance of SRL [3].

Educational Resources linked to Technology can support SRL during every phase. MOOCs provide learning materials that enable self-paced learning which requires SRL skills. In a study by Kang et al., students exhibited positive attitudes toward a *soft classroom*, where no attendance of the weekly class was required, and achieved better learning outcomes. [28]

ePortfolio can support SRL, especially during the forethought and self-reflection phases. This provides a structured learning path [2].

Feedback Tools can support SRL during the self-reflection phase. They support students during (self-)assessment [11].

Gaming Technology: According to Wiyarsi et al., an educational mobile game led to significant improvements during the planning phase, motivated during the performance phase, and provided students with a visualization of their developmental process in the self-reflection phase [66]. Game-based learning requires learners to apply their subject knowledge, leading to a high level of attention. [65]

Immersive Technology can support SRL during every phase. *Immersion, flow, and presence enhanced self-efficacy while absorption and immersion enhanced self-regulation.* [16]

Learning Analytics can support SRL during every phase. LA can assist students in setting goals, tracing progress, and periodic self-evaluation to reflect their own learning status [33], and external feedback provided by LAD can positively influence students' SRL abilities [25].

Mobile Learning: A systematic review by Palalas and Wark showed a connection between mobile learning and enhanced SRL, SRL enhancing mobile learning, or mobile learning and SRL improving other learning factors, such as health or curriculum development. [50]

Personalized EdTech can support SRL in every phase. PLEs can help with goal definitions and recommendations for learning strategies [40]. Effective self-monitoring is possible using ITS [5]. Lim et al. [38] reported that personalized scaffolds yielded significantly better essay scores.

4.3   Choosing the right Learning Context

In **online settings**, Broadbent et al. [13] indicated that educators should not assume that online learning occurs in the same way as in traditional settings, and that they need to choose technologies that fit their pedagogical purpose and medium. According to a systematic review by Broadbent and Poon [12], peer learning should be prioritized in online learning contexts. Hybrid solutions such as **blended learning** can benefit from both approaches. *Well-designed personalized learning environments can transform both teachers' and students' behaviors and encourage students' academic growth* [9]. When SRL is embedded without the students in mind, as in an instructor-focused learning context, SRL could result in a key inhibitor of satisfaction [1].

EdTech can also be used for **remote learning scenarios**, as required during COVID-19-restrictions. Oinas et al. [46] stated that, for middle school students, peer learning during remote learning periods had the strongest correlation with positive experiences, and SRL skills should be emphasized.

The EdTech deployed should be stable. When software has technological difficulties or is not well integrated into the learning context, no significant improvement in SRL is possible [34].

4.4   Limitation

This review has several limitations. First, only one database (Scopus.com) was used, therefore important research that was not indexed in Scopus.com could have been missed. Second, only one search string was used, and abbreviations from keywords such as *Educational Technologies* were not included. Despite these limitations, in comparison with other systematic literature reviews, such as [12,63], a broader range of EdTech was included in our review. Further on, SRL models described in other reviews [51,63] were also found, as shown in Figure 7.

5   Conclusion

The importance of SRL, which fosters academic success and lifelong learning, remains undisputed. Fostering SRL skills is important, and EdTech can support the different phases of SRL. This scoping review contributes to answering the *ultimate question* according to Zimmerman [71]: *How do students become masters of their own learning processes?*

5.1   EdTech-SRL-Synergy-Map: How EdTech can promote SRL

In accordance with the methodology paper for scoping reviews from Peters et al. [52], to *clearly illustrate the nature of the results*, we present in Figure 8 an EdTech-SRL-Synergy-Map. A Venn diagram with the three different phases of SRL, according to the SRL model from Zimmerman [71], enhanced with the identified strengths of EdTech from this scoping review. This visualization depicts the tools to be used to enhance SRL in the three different phases. In addition, the intersections in Figure 8 show tools that can be used in multiple phases.
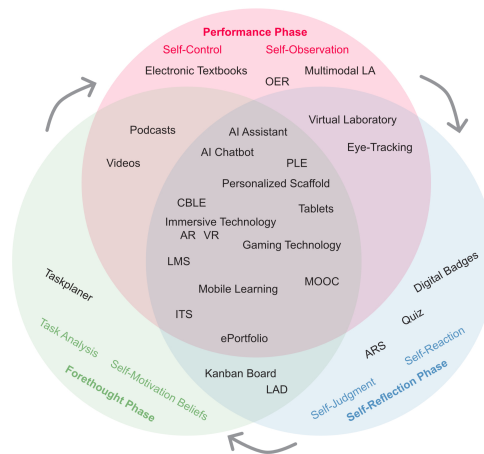

Fig. 8. EdTech-SRL-Synergy-Map, Adapted from Zimmerman's SRL Model [71]

Forethought Phase (Task Analysis and Self-Motivation Beliefs) *Task Planner:* Helps in setting clear learning objectives and organizing tasks effectively, enhancing motivation by breaking down goals into manageable activities.

Performance Phase (Self-Control and Self-Observation) *Electronic Textbooks and Open Educational Resources (OER):* Provide accessible content and interactive elements that engage learners and support active learning strategies. *Multimodal LA:* Offers insights into learners' engagement patterns during learning activities, helping them adjust strategies for better focus and comprehension.

Self-Reflection Phase (Self-Judgment and Self-Reaction) *ARS, Quiz, and Digital Badges:* Engage learners in self-assessment through quizzes and reward learning achievements, encouraging reflection on progress and motivating further learning.

Forethought and Performance Phase *Videos and Podcasts:* Serve as versatile learning resources that can spark interest and motivation during the planning stage and provide in-depth content for active learning during the performance phase.

Performance and Self-Reflection Phase *Eye-Tracking LA:* Offers detailed feedback on learners' engagement and focus during learning activities, facilitating reflection on study habits and comprehension strategies. *Virtual Laboratory:* Provide hands-on practice in a controlled environment, allowing for experimentation and immediate application of concepts, followed by reflection on outcomes and learning processes.

Self-Reflection and Forethought Phase *Kanban Board:* In addition to its use in informed planning, it can also facilitate reflection on completed tasks and the effectiveness of learning strategies. *LAD:* Provides a comprehensive overview of learning achievements and patterns, aiding in reflective practice and informed planning for future learning endeavors.

Forethought, Performance, and Self-Reflection Phase *AI Assistant and AI Chatbot:* Offer personalized guidance throughout the learning process, from setting goals and finding resources to providing feedback and encouraging reflection. *Personalized Scaffold, PLE, and Computer-Based-Learning-Environment:* Adapt to learner's needs across all phases, offering tailored content, practice opportunities, and feedback. *Tablets, Immersive Technology, Gaming Technology, MOOC, LMS, Mobile Learning, ITS, and ePortfolio:* These tools collectively support all SRL phases by providing flexible, engaging, and personalized learning experiences, from goal setting and content engagement to reflection.

5.2   Further Research

As SRL is important for academic success, there is a shortage of research in the primary and secondary education sectors. Further research could reveal the potential of SRL in secondary education, which will also impact tertiary education in the long term. In addition AI and generative AI have evolved rapidly in recent years and fundamentally shattered the possibility of personalizing education. Because all three phases of Zimmerman's SRL model (forethought, performance, and self-reflection) [71] could be supported by AI, further research is required in this regard, too.

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