

Received 27 July 2024, accepted 20 September 2024, date of publication 30 September 2024, date of current version 10 October 2024.

Digital Object Identifier 10.1109/ACCESS.2024.3470114

SURVEY

Systematic Review of Self-Regulated Learning With Blended Learning in Digital Space

M. S. FAATHIMA FAYAZA^{1,2}, (Member, IEEE),
AND SUPUNMALI AHANGAMA¹, (Senior Member, IEEE)

¹Department of Information Technology, University of Moratuwa, Katubedda, Moratuwa 10400, Sri Lanka

²Department of Information Technology, South Eastern University of Sri Lanka, Oluvil 32360, Sri Lanka

Corresponding author: Supunmali Ahangama (supunmali@uom.lk)

This work was supported in part by the Faculty of Information Technology, University of Moratuwa; and in part by the Senate Research Committee, University of Moratuwa.

ABSTRACT Technology enhancements introduce novel learning modes by replacing traditional face-to-face learning. Blended learning (BL) has emerged as the new normal, combining face-to-face instructions and online elements. Successful BL requires a high self-regulation capability among the learners. Technology can enhance these Self-Regulated Learning (SRL) capabilities. This paper reviews 66 papers published in the Scopus, IEEE Xplore, Google Scholar, and ScienceDirect databases between 2016 and 2024 (till March) using the PRISMA model. As per the review, self-reported data using a questionnaire is the most used mechanism to collect data on users and most of the studies used university undergraduates as a learner group. Very few researchers work collaboratively, though enhancement of the collaborative work will bring better outcomes. In general, SRL positively impacts learning outcomes in the BL context. Cognitive, metacognitive, motivational, and resource management strategies enhance learning, and emotional engagement is enhanced by the user interface of learning platforms. However, some strategies do not have an impact on the BL environment. This study suggests the importance of understanding the long-term impact of SRL and how different strategies impact the learning outcomes and their subsequent performance. Also, it is necessary to apply the different SRL strategies to different contexts to generalize the findings.

INDEX TERMS Blended learning, digital space, self-regulated learning.

I. INTRODUCTION

In the 21st century, emerging disruptive technologies are rewriting the evolving educational ecosystem and paving the way for modern teaching and learning experiences. Educational institutions stepped towards the new norms of education and started to adapt to constant transformations to survive in the competitive environment. Technology has become a cornerstone of education and has changed traditional paradigms. Today, Distance Learning (DL), Blended Learning (BL), Online Learning, e-learning, Flipped classrooms (FC), and Massive open online courses (MOOCs) have emerged as a new normal of education replacing the traditional classroom settings [1]. These digital learning spaces (DLS) support quality education regardless of place or time

The associate editor coordinating the review of this manuscript and approving it for publication was Jeffrey Jonathan Yackley¹.

restrictions, confirming ease of access and flexibility for learners. Further, digitalization supports customization [2], [3] and student-centered learning. The technology supports the learners at risk [4], mitigates undesirable learning activities [5], and goal-setting [6], increases self-efficacy [7] and also reduces test anxiety among the learners [8]. The challenging part of digital learning is the dropout ratio of 8-20%, which is higher than in traditional classroom settings [9], [10], [11], [12]. The success of DLS in education strongly depends on a learner's ability to independently and proactively participate in the learning process [11]. This process is known as self-regulated learning (SRL). Though SRL is linked with traditional education, in DLS, its impact is even more evident since there is no direct supervision of the students by the instructors [2]. DLS has led to a turn from teacher-centered learning to SRL and is affected by many factors, the most critical factor being students working

along with technology devices. This demands the learners to have good discipline and self-control over their learning. Self-control is not an inbuilt characteristic of everyone [2]. It is a learning process that needs to be constantly developed. Therefore, SRL strategies play a wider role in the new norm of learning.

Among all the DLS, BL has a more preferred mode since it combines online and face-to-face learning. BL with strong support services such as resources, environment, personnel, teaching method, and platform for learners provides flexible learning [13]. Generally, BL (based on the level of face-to-face and online learning) can be categorised as (a) Flipped classroom (online learning, in-class activities); (b) Learning and practice are equally divided into in-class and online; and (c) Learning and practice are equally divided into incalls and online accompanied by collaborative learning [14]. However, the success of this environment and the characteristics that make them successful remain in doubt [15]. Furthermore, lower self-regulatory learners face a challenge in succeeding in DL environments and people with high self-regulation perform well [15]. The effectiveness of learning depends on the environment, learning activities given to learners, and the information given to improve learning activities [16]. Therefore, in any kind of DLS, it is necessary to understand the SRL features that support effective learning. Moreover, Self-regulation in BL has received relatively less attention compared to other technology-mediated educational processes such as MOOCs [17]. This study investigates the SRL strategies used in DLS with special reference to BL to answer the following questions:

1. How is SRL used to enhance the Technology Enhanced Learning?
2. How is SRL used to improve academic performance?
3. What are the key principles/theories used to analyse the SRL in Blended Learning?
4. What are the SRL strategies investigated in the BL context?

This study reviewed 66 papers published between 2016 and March 2024 in Scopus, IEEE Xplore, Google Scholar, and ScienceDirect databases. A descriptive and content analysis is carried out to understand the contemporary trend in SRL in DLS, SRL's impact on learning outcomes, and to identify the research gap in the area.

II. THEORETICAL BACKGROUND

The literature related to SRL, DLS, and BL are explained below with the relevant theoretical models developed.

A. SELF-REGULATED LEARNING

SRL originated from psychology [18] in the social cognitive perception [19] and combines cognitive, metacognitive, motivational, and management processes in learning [20], [21]. SRL is a complex process linked with the learners' viewpoint of learning, commitment, skills, context, and activities [18]. Learners engage with different SRL strategies during their learning process; for example, planning,

goal setting, organization, self-evaluation, and monitoring. Researchers focus on SRL from different perspectives [22]. For instance, Boekaert's [23] model focuses on motivation and Efklides's [24] model focuses on metacognitive factors.

Zimmerman is one of the pioneers of SRL [5], [25], [26] and defines self-regulation as "the degree to which students are metacognitively, motivationally, and behaviorally active participants in their learning process". Zimmerman constructed three versions of SRL models: the "Triadic Analysis of SRL" (1989), the "Cyclical phases model" (2000) generally identified as the Zimmerman model, and the "Multilevel model" (2009) [22]. Furthermore, Zimmerman's models constructed five instruments for measurement; namely, "Self-Regulated Learning Interview Schedule (SRLIS)", "Measures to assess SRL in experimental training settings", "microanalytic measures", "self-efficacy to self-regulate", and "Academic Self-Regulation Scale (A-SRL)" [22].

In addition, Boekaerts [20], [23] created two models: the "structural six components model" and the "adaptable learning model - Dual processing model". The Boekaert models use the "online motivation questionnaire (OMQ)", "Interactive Learning Group System (ILGS)", "Confidence and Doubt scale", and "neural networks for SRL" as research instruments [27]. Hadwin et al. [28] investigate SRL from a metacognitive perspective based on the information processing theory. However, no research instrument was developed based on the Winne and Hadwin model. Pintrich's [29] model constructed the "Motivated Strategies for Learning Questionnaire (MSLQ)". Efklides [24] developed the "Metacognitive and Affective Model of Self-Regulated Learning (MASRL)" and developed two research instruments: "self-concept for a language task" and "Metacognitive experiences questionnaire". Also, Hadwin, Järvelä, and Miller [28] present "socially shared regulated learning (SSRL)", for which no research instrument has been developed yet.

Panadero [22] studied six distinct SRL models, namely, the Zimmerman cyclical phase model [5], [26]; Boekaerts [20], [23]; Winne and Hadwin [28]; Pintrich [29]; Efklides [24]; and Hadwin, Järvelä, and Miller [28] and summarize that, SRL models share three common phases: planning, performance, and reflection [22]. First, the Planning phase mainly involves examining the task, setting goals, planning, and self-motivation. Task analysis is the initial step of this phase [30]. Second, in the Performance phase, the task is executed while monitoring the progress [30]. The two main objectives of this phase are self-control and self-observation [30]. Here, learners control task approaches, time, environment structure, and help-seeking. Self-observation covers, "cognitive self-regulation" and self-recording [30]. Third, the Reflection phase includes self-judgment as its main part. Learners evaluate performance success or failure and identify the reason for it, and how it can influence the learners' future [30].

Further, SRL phases contain various sub-processes that vary across models but still share conceptual similarities [17]. Yet, different SRL sub-processes demand varied involvements at the different stages of learning. However,

Hikkinen et. al. [31] concluded that when analyzing, the learning behavior of a learner learning analytics needs to impact all the phases of SRL.

B. SELF-REGULATED LEARNING IN DIGITAL LEARNING SPACES

In the literature, there are several studies conducted to identify SRL support in DLS. However, the focus of these studies is different. For example, some researchers focus on a particular SRL strategy such as self-efficacy [4], or peer learning [1]. Some other researchers focus on a particular factor; for example, the environmental impact [13]. Also, some other studies focus on specific modes of learning, such as online learning [6], flipped classrooms [7], and blended learning [8].

The challenging part of the BL environment is self-regulation. BL's seven key features that support the SRL are: "authenticity", "personalization", "learner-control", "scaffolding", "interaction", "cues for reflection" and "cues for calibration" [15]. Even though researchers are unable to identify the association between these attributes and the learner's self-regulation [15] it is also necessary to consider the four essential pillars of the BL environment; namely, "flexible environment", "learning culture", "intentional content", and "professional educator" [30]. BL success and SRL strategies heavily depend on instructor action in the BL context and learning environment [32]. Therefore, knowledge about these factors supports course design and pedagogical success.

Hunutlu [3] pointed out twelve SRL strategies: "self-evaluation", "goal setting", "time management", "help-seeking", "task strategy", "environmental structuring", "self-efficacy", "strategic planning", "self-observation/monitoring", "self-satisfaction", "achievement motivation", "effort regulation/persistence" and fifteen key attributes: "motivation", "interaction-feedback", "metacognition", "use of digital tools", "pedagogical support", "autonomous learning", "good learning experience", "positive belief", "the reflection of the process", "self-efficacy", "authenticity", "scaffolding", "cultural interest", "critical thinking", "the flexibility of time" based on the publications between 2018 and 2022 online learning. Eggers and Voogt [32] concluded that four types of strategies are based on the literature metacognitive, cognitive, motivational, and management. Among these, Goal setting and planning are the most discussed strategies while help-seeking, environmental structuring, and rehearsing are repeatedly overlooked in the previous studies [18]. In [2], researchers mainly reviewed the 48 Journal Citation Reports (JCR) works related to peer collaboration. The paper concluded that learners could control one another when they work simultaneously and there is a possibility to manipulate prior knowledge.

Researchers utilize different research instruments to analyze self-regulation. The SRL evaluation mechanism in preference order: (a) Self-reported questionnaire, (b) Learning analytics, (c) Interview, (d) Think-aloud protocols, (e) reflective documents, (f) Observation [30]. However, the base

mechanism to measure SRL is a questionnaire and the instrument is the Motivation and Self-regulation of Learning Questionnaire [32].

The limitation in the literature is that some SRL works failed to consider the academic outcome, but the SRL theories were established to explain the differences in the learning outcome and therefore it is taken into account [2]. Lai and Hwang conducted a study using seven SSCI Journals from 2010 to 2020 based on e-learning [18]. The study summarizes that 58% of works fail to consider the possible strategies for individual SRL stages and 40% fail to consider practical applications of SRL [18].

Table 1 summarizes the review studies identified in this current study related to SRL and BL. From these researchers observed there is a necessity to understand the available studies related to SRL in the BL.

III. METHODOLOGY

This study applies the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) method [37] as a guide for the literature analysis. This study uses IEEE Xplorer, Scopus, Google Scholar, and ScienceDirect databases as primary data sources and collected articles from January 2016 to March 2024. Table 2 summarizes the collected paper details.

The study utilizes "blended learning", "BL" "blended instruction", "blended teaching", "hybrid learning", "hybrid instruction", "hybrid teaching", "hybrid course", "flipped classroom", "flipped learning", "education technology", "self-regulated learning", "self regulated learning", "SRL", "self-directed learning", and, "self-management", "metacognitive" as base keywords for search. The keywords mainly focus on BL and SRL. Furthermore, researchers included "self-regulation" with and without hyphens. To search more broadly, authors utilize wild card characters with search terms. Boolean operators such as "AND" and "OR" are used to enhance the search query. The searches were performed on titles and abstracts. The search query is adjusted according to the database search functionalities, therefore searches were conducted, by keywords and/or subject-subject, combining or incorporating autonomous search terms. For example, the search query used in Scopus is given below.

((*"blended learn*" OR "blended instruction*" OR "blended teach*" OR "hybrid learning" OR "hybrid instruction*" OR "hybrid teaching" OR "hybrid course*" OR "flipped classroom*" OR "flipped learn*" OR "education tech*" "educational tech*"*) AND (*"self-regulat*" OR selfregulat* OR srl OR "self-direct*" OR "self direct" OR "self-manag*" OR "self manag*" OR "meta-cognit*" OR metacognit**))

This study follows the following selection criteria for eligibility: (a) papers need to be published between 2016 and March 2024, (b) the article needs to be written in English, (c) full paper available, and (d) the paper discusses the SRL in the DLSs. This study included journal and conference papers

TABLE 1. Review studies based on SRL and BL.

No	Problem statement/ Research question	Year	Data source	No. of papers used	Finding	Research gaps/Limitations
[33]	RQ1: How far researchers examine learning outcomes using cognitive, affective SRL in the FL context RQ2: FC impact on cognitive strategies RQ3: FC impact on effective strategies RQ4: FC impact on SRL	2008 - 2017	Web of Science	307 articles identified 22 papers selected for the study	Generally, FC positively impacts SRL even though there are mixed results. Cognitive, affective, and SRL outcomes also have mixed results.	Studies are based on scientific background The gap needs to be learned, success of learning is a result of instructional deliverance or a pedagogical approach?
[34]	RQ1:Relationship between SRL and programming learning. RQ2: What methodological procedures were used?	Until March 2021	ACM, IEEE, Science Direct, Eric	92 papers were selected, and 6 were included in the study	Self-efficacy and metacognitive strategies positively impact learning. Cognitive approaches and intrinsic beliefs not associated	Authors use different scales for the same instrument based on their study, so providing a general conclusion is challenging
[32]	RQ1: The most effective instructional mode in BL. RQ2: The instrument mostly used to measure SRL in BL	2000 – 2021	Web of Science Eric, Scopus PsycInfo	21 papers were selected out of 691 search result	Need more attention on SRL in BL BL environment must care about cognitive, metacognitive, motivational, and management and the BL designer needs to be aware of that.	Most of the studies used self-reported data to analyse In most of the studies sample size is small. Studies focus on specific curriculum
[2]	SRL and peer learning	2010-2022		48 papers selected out of 272 search result	Learners are self-regulated among them in peer collaboration. SRL supported through feedback, tools, and inspiration	Quality of SRL not acknowledged Some studies did not consider academic outcomes in relation to SRL
[16]	BL attributes that support SRL	1985-2015	Web of Science, ProQuest, EBSCOhost, Science Direct and OvidSP	95 papers	Seven key attributes of BL authenticity, personalization, learner-control, scaffolding, interaction, cues for reflection, and cues for calibration	Still no clear relationship between attribute and learners' SRL behavior
[18]	RQ1: SRL strategies used in BL RQ2: application domain, learning outcome, and participants	2010-2020	publications in seven SSCI journals The British Journal of Educational Technology, Computers & Education, Educational Technology & Society, Educational Technology Research and Development, Interactive	177 papers	Good SRL guidelines improve the learner's attitude and performance	Most of the studies focus on the environment

TABLE 1. (continued.) Review studies based on SRL and BL.

			Learning Environments, Internet and Higher Education, and the Journal of Computer Assisted Learning.			
[35]	RQ1: Which SRL strategy enhance foreign language learning RQ2: Utmost effective SRL interferences	2010-2022	Google Scholar ERIC Scopus	20 papers	No particular consistent method for improving foreign language learning. metacognitive exercise, SRL training programmes, cognitive exercise	Studies failed to focus on long-term effects
[36]	SRL strategies because they failed to understand		PsycINFO ERIC databases for peer-reviewed sources published in the English language between 1st January 2000 and 31st August 2018.		Metacognitive is most commonly used and studied.	

TABLE 2. Data source with the number of papers.

Database	Number of papers collected
IEEE	52
Scopus	39
Google Scholar	43
ScienceDirect	107

and excluded the thesis, book chapter reports studies in other languages, and published before 2016. Fig. 1 outlines the paper selection process.

The paper selection was carried out in three phases. In the first phase, researchers focused on the title and abstract of the paper and removed the papers that did not meet the requirements. In the second phase, the authors focused on the full paper with a special focus on the overall subject, research gaps identified, theories developed and used, methodology, datasets, and bibliographical references, and removed the papers that were not in the research scope. Finally, the authors did a thorough study of the papers selected for review and created a summary of the study. The summary focuses on the aim, sample size, procedure, research instrument, authors, country, year of publication, and dependent independent variable. In the second and third phases, researchers conducted several discussions to resolve the discrepancies in the paper selection process and finalize the papers that met the inclusion-exclusion criteria. The authors synthesized literature works and answered the research questions.

IV. RESULTS AND ANALYSIS

This study utilizes 66 papers selected as mentioned above. Researchers observed an increasing trend in the number of publications related to SRL and DLS. In 2016, one article, in 2017 three articles, in 2018 six, in 2019 seven, in 2020 nine, 2021 eleven, in 2022 thirteen, in 2023 fifteen, in 2023 fifteen, and till March 2024 one article was published. Fig. 2 elaborates on the growing tendency in the number of publications. Subsequently, the researchers of this study performed descriptive and content analysis using the chosen papers. The results of the descriptive and content analysis are explained in detail below:

A. DESCRIPTIVE ANALYSIS

Researchers analyse the bibliography data using VOSviewer_1.6.20 software. Fig. 3 shows the word cluster generated from the selected paper title and abstract. The cluster shows 37 token words that occur more than 20 times out of 4,109 words among the title and abstract. This token of words is clustered into four groups. These clusters are represented using different colors. Only 0.9% of common words appear among the title and abstract. This may be because even though the paper mentions SRL and BL, those papers may be focusing on different aspects. The word cluster shows learning, study, student, blended learning, flipped classroom, self-regulation, strategy, motivation, technology, education, research, and course are some prominent terms in the cluster. This illustrates that motivation is the

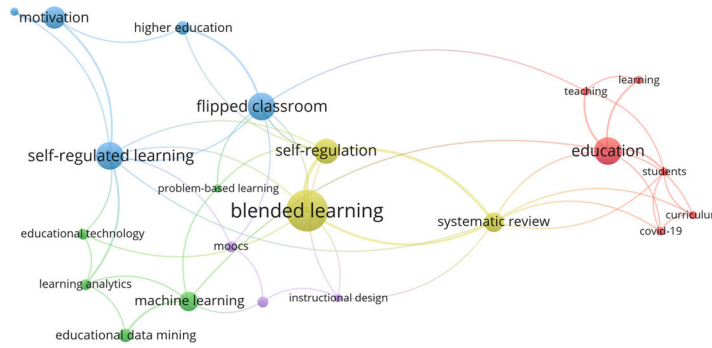


FIGURE 4. Most significant user defines keywords.

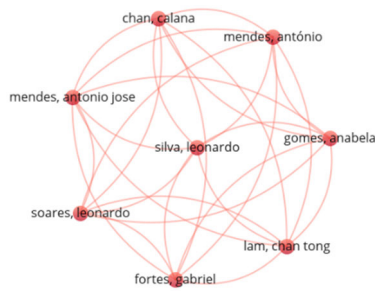


FIGURE 5. Collaborative authors.

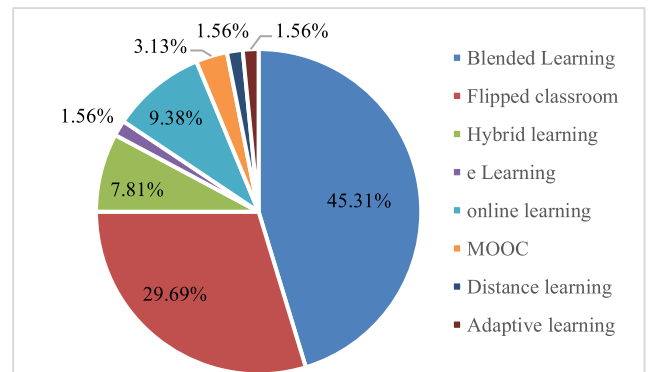


FIGURE 7. Learning mode used.

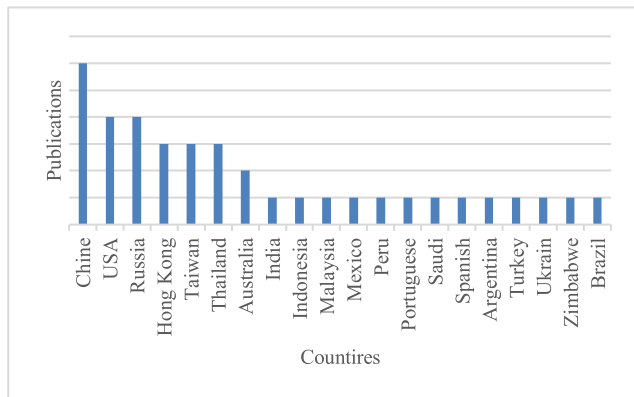


FIGURE 6. Publication distribution around the world.

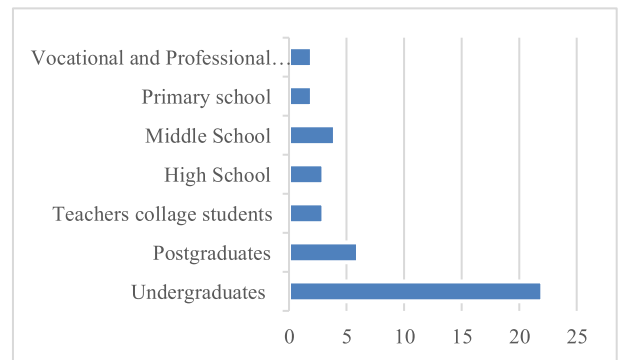


FIGURE 8. Participant level.

systematic review, education, and machine learning are key-words that appear more than five times in the selected papers. Furthermore, machine learning, educational data mining, and learning analytics also appear in the keywords cluster. That is, this shows the techniques used to analyze the SRL strategies in the BL environment.

Fig. 5 shows the authors who worked together. Out of 339 authors, only 8 worked together in more than 3 papers. This is 2.35%. This shows the necessity for researchers to work together to get more new knowledge. Fig. 6 shows the countries that published the greatest number of publications. The countries involved in the works are in order based on the number of publications: China (15%), the United States

of America (10%), Russia (10%), Hong Kong (8%), Taiwan (8%), and Australia (5%). These countries are developed countries. Very few studies are conducted based on developing countries. For example, India and Zimbabwe have one paper each.

Fig. 7 shows the different learning modes used in the literature. The most preferred mode is BL (45%), followed by Flipped classroom (30%), online learning (9%), Hybrid learning (8%), Massive Open Online Courses (MOOC) (3%), Distance Learning (1.5%), e-learning (1.5%) and adaptive learning (1.5%).

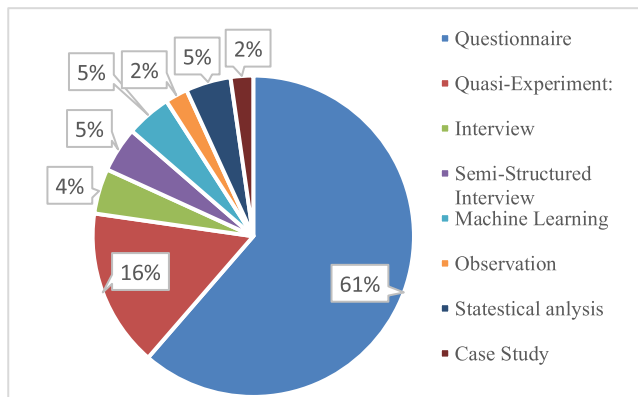


FIGURE 9. Shows the experimental method used by the studies.



FIGURE 10. SRL strategies & research instrument used.

Fig. 8 summarizes the participants used for the studies. Researchers used different kinds of learner groups to test SRL in BL. Most of the researchers tested on undergraduate students while a few other studies were on postgraduates, school students, and college students. Some researchers have given special attention to training teachers’ college students SRL. This may be due to understanding future teachers’ SRL strategies and to understand their level of understanding of SRL. Furthermore, researchers focus on different categories of school students, for example, primary, secondary, and high school.

Most of the researchers used questionnaires as a research methodology to measure the SRL strategies. Followed by Quasi-experiments, interviews, semi-structured interviews, machine learning, statistical analysis, case studies, and observation are used. Fig. 9 shows the experimental mechanism used by the studies.

Fig. 10 summarizes the different SRL strategies used in the literature. Some studies investigate SRL in general and some studies focus on a particular strategy. Researchers use the Motivation and Self-regulation of Learning Questionnaire (MSLQ) and Online Self-Regulated Learning Questionnaire (OSLQ) as the standard research instrument to collect data. Studies have focused more on self-efficacy, followed by goal

TABLE 3. Subject research focus.

Digital Logic (DL)	English as a Foreign Language
Introduction to Educational Technology	English Curriculum and Instruction.
Introductory Educational Technology Course	English Writing Competency
Management and Industrial Engineering Degree Programmes	Educational Research
Accountancy	Fundamental Information Technology in Business
Art	Theory and Practice of Translation of Epistolary Texts (French)
Biology	International Business
Business Ethics and CSR	Marketing Course
Business, Creative Industries, Social Sciences, Natural Sciences, Health and Engineering Programmes.	Masters of Business Administration (MBA), Masters of Public Administration (MPA), and Masters of Aviation (MS Avit)
Chemical Engineering	Non-Science Majors General Biology Courses
Chinese Language and Literature	Physical Education
Civic Education	Physics
Computer Science	Project Management
Dental Students	Russian Language and Culture of Speech
Engineering	Science
English	Software Engineering
Technology for Business Application	Surgical Nursing

setting and motivation, peer learning, and feedback. Some studies focus on self-regulation in an overall context.

Most of the researchers analysed SRL to a particular subject. Table 3 summarises the subject that researchers focus upon to study SRL in BL. These subjects vary from computer science, language learning, Education, nursing and biomedical, business, and dental.

Based on the research context the researchers used a varied number of samples for their study. Some researchers used a small sample size such as thirteen [38] while some studies used thousands, for example, 1,914 samples [39]. When researchers utilized online communities, they collected more samples than in a physical setting. Furthermore, the sample size is low when data collection is done through interviews, semi-structured interviews, quasi-experiments, and observations.

B. CONTENT ANALYSIS

With technological advancement, BL is a very efficient method of learning and capable of verifying the path of innovation at all levels of education. The objective of BL is innovative advancement and self-learning of the individual [40]. However, those who are new to the BL

TABLE 4. Details the research question, approach, dataset size, and results of the papers.

Reference	Research question / Research gap identified	Learning Mode	Approach/ Instrumentation/ Methodology	Dataset size	Result
[44]	RQ1: In what way do learners understand behavioural engagement, cognitive engagement, and emotional engagement in BL? RQ2: How do they perceived teacher support, situational interest, and self-regulation influence the Behavioural, cognitive, and emotional engagement in BL?	BL	Teacher support scale, situational interest scale, self-regulation scale, engagement scale questionnaires	302 students (177 female, 125 male)	Instructor assistance has positive impacts on behavioural and cognitive engagement, but not on emotional engagement. Students' emotional engagement is influenced by the user interface friendliness and interactivity of the online learning platform. Situational interest is only a positive forecaster of emotional engagement
[45]	RQ1: What factors improve practitioners' skills in lifetime learning via education and putting new learning into practice?	BL	Case study based on Biggs 3P model (surface learning, deep learning, strategic learning) Biggs Two-Factor Study Process Questionnaire (R-SPQ-2F) Revised Two-Factor Study Process Questionnaire (R-SPQ-2F) Online Learning Readiness Scale (OLRS)	Ten organizations, three courses, twenty for questionnaire, three for interview	Intrinsic motivation is the root cause of lifelong learning.
[46]	RQ1: To what extent is MSLQ reliable and valid when employed by Chinese students? RQ2: To what degree is SRL applied in Chinese middle schools? Is that impacted by gender or geographical location? RQ3: Analyze the relationship between learning motivation learning strategy and academic performance.	BL	MSLQ	3,389 samples from nineteen middle schools from 11 cities	MSLQ has good internal consistency and validity. Motivation is higher than other strategies. Other strategies in order: intrinsic value, self-efficacy, cognitive strategies Test anxiety is high in students. Motivation and self-efficacy directly affect performance.
[7]	RQ1: How do students feel about flipped learning experiences? RQ2: What are students' perceptions of the approaches helping their readiness in a flipped classroom setting?	Flipped classroom	Mixed method	15 postgraduate teachers and college students	Flipped learning demands good preclass work and pre-class work needs self-regulation. Even its challenges in case of unfamiliar content. Instructors need to care about low-level learners for successful learning.
[47]	RQ1: How does bDBL affect students' understanding design skills and intrinsic motivations in engineering? RQ2: In what way do learners understand bDBL?	BL	Survey with subscales: interest, perceived expertise, apparent choice, anxiety Semi-structured interviews	60 students	Online platform support with high volume of content lacks in motivation.
[48]	RQ1: What effect does the use of video lectures as learning materials have on the learning process?	Flipped classroom	A questionnaire with the closed and open-question Group discussion	33 students from high school who are following technical degrees in industrial processes.	90% of learners totally agree video helps to understand the concept. Learners stressed that videos "turn the subject more dynamic, enjoyable and bearable" while being "funnier than reading the course notes". Video makes classroom dynamic Video helps students to schedule and organize their time.

TABLE 4. (continued.) Details the research question, approach, dataset size, and results of the papers.

[49]	RQ: Find pupils' and instructors' chosen support for technology-based BL	BL	Questionnaire	20 instructors and 343 students from Vocational and Professional Education Training (VPET)	Pupils preferred peer learning as well as social media chat
[50]	How pre-class activity impacts on in-class learning	Flipped classrooms	MSLQ	135 junior pre-service teachers	Application of self-efficacy, cognitive, and metacognitive strategies significantly improved.
[51]	How learner's readiness impact learners' satisfaction	BL	Questionnaire with demographic, learner readiness, and learner satisfaction	325 undergraduates	BL implementation needs to care about learner satisfaction. Five critical aspects of student satisfaction: performance expectation, SRL, online communication self-efficacy, motivation for learning and learner control
[52]	RQ1: Examine degrees of learner motivation and application of SRL strategy in English writing RQ2: How motivation and SRL strategies differ between high and low-level achievers.	-	Questionnaire – Motivation & SRL strategies.	523 primary school students	Interest not associated with high-performance SRL. Interest and self-efficacy are considerably associated with average learners' SRL. However, self-efficacy does not impact lower-level learners.
[53]	RQ1: How self-efficacy differs in the traditional and flipped classroom RQ2: How academic performance differs in the traditional and flipped classroom	Flipped classroom	Satisfaction questionnaire, interview	37 undergraduate students who are following introduction to mathematics education	Flipped classrooms improve self-efficacy Flipped classrooms improve the SRL.
[54]	RQ: The relationship between cognition, motivation, metacognition, and learning performance	BL	Student Engagement and Disaffection in School questionnaire to measure the negative and positive emotion MSLQ for motivation	222 undergraduates from Management and Industrial Engineering for face-to-face context 116 undergraduates from Applied Computing in Biological Science	Peer learning, text anxiety, and help-seeking are more on BL learners than traditional. BL improves the SRL strategies.
[55]	Effectiveness of flipped classroom on math problem solving	Flipped classroom	Quasi-experimental with questionnaires	46 students	Positively impact on math problem solving
[56]	Effects of Media literacy on Face-to-face and bl context	BL	Questionnaire and checklist	85 Agricultural Technology undergraduates	No relation between learning methods and SRL (low and high) on learners' media literacy
[57]	Analyse the SRL strategies in different stages of the course	Distance Education	Questionnaire	251 Accountancy undergraduates	Application of SRL strategies (“review of note, test and bibliography”, “environmental structuring”) higher in distance learning than face to face-to-face learning
[50]	Find the impact of earning content-providing approach	Flipped classroom	Quasi-experiment with Pre-class, assessment, and final exam score	657 undergraduate non-science majors in General Biology courses.	Video lectures outperform interactive online material and textbook-style reading. Student-centered flipped classrooms improved learning outcomes
[58]	Soft skill development in BL among engineering students	BL	Questionnaire	48 Computer Engineering students	BL improved SRL with experience.
[59]	RQ1: Learners' views of support, SRL and critical thinking skills in involvements using FCM; RQ2: The connection between learners' views of support, SRL and critical thinking skills; RQ3: Determine students' general perceptions of FCM learning	Flipped classroom	Critical thinking skills test Perceptions-of-support questionnaire Barnard et al. SRL questionnaire	69 Grade 8 students	Critical thinking and SRL, critical students SRL

TABLE 4. (continued.) Details the research question, approach, dataset size, and results of the papers.

[60]	RQ: Does an integrated learning environment play a role in the learning outcome?	Flipped classroom	Survey and interview	63, 3 rd year undergraduates who enrolled in integrated learning course	An integrated learning environment influences learners' engagement motivation and performance.
[61]	Does a hybrid learning environment enhance reading speed?	Hybrid learning	Reading speed test, reading comprehension test	30 students	Reading speed or comprehension is not supported by the learning environment
[62]	Discovers the association between self-regulation profile and gratification	Flipped classroom	ILS inventory and satisfaction questionnaire	178 undergraduates	Passive students have love satisfaction

context are not ready for SRL [41]. Even though experienced students are willing to accept the BL, they still prefer the traditional methods of learning [41]. For example, Nuankaew et. al. [42] found out that Thailand undergraduates are still interested in formal education. Furthermore, with the technology-enhancement the Z generation prefers to collect information from the web, but the Z generation still prefers online and face-to-face combinations in their learning since they are digital migrants and not digital natives [43]. Table 4 presents the research questions, and approach dataset size with findings of the selected publications for this study.

V. DISCUSSION

In recent times, SRL in DLS has been significantly grabbing the attention of researchers and educational institutes. Researchers continuously work to identify the impact of self-regulation strategies on learning outcomes. However, Boekaerts [16], [32] and Pintrich [16] group SRL strategies under three main clusters namely, cognitive, metacognitive, and motivational based on information availability and amount of information. Dignath and Voogt [32] introduced resource management strategies. This section discusses these strategies and their impacts. These areas in relation to the articles considered for this study are discussed in detail below.

A. COGNITIVE

Cognitive strategies are a cornerstone for successful learning. Many studies discuss the importance of cognitive skills in enhancing learning outcomes [63], [64]. However, still, there is no agreed definition for cognitive skills [65]. Richardson and Newby [65] explained cognitive as the inspiration and approach applied by learners in the educational procedure. In their viewpoint, it is the level of the learner's involvement in educational activities, incorporating thinking, tactics, and endeavors to create complex solutions [65]. In simple terms cognitive is about mental contribution in education which involves obtaining information, coding information in memory, and reclaiming it when required. Rehearsal, elaboration, and organization are the subclass of cognitive strategies [32]. SRL and frequent revision play a critical role in successful learning [66]. However, in the online and BL environment, rehearsal does not impact the learning outcome [54].

Self-regulation has a positive impact on cognitive engagement [44] though cognitive strategies do not impact programming learning outcomes [67]. Furthermore, BL positively impacts cognitive outcomes [68]. Cognitive strategies can be influenced by previous knowledge and motivation [32]. In a BL environment, with the support of technology elaboration, an organization can improve. For example, recorded video support for revising the content again and again.

B. METACOGNITIVE

Metacognition is a higher-order thinking process that helps to evaluate the learners' cognitive process. Metacognitive strategies are grouped into planning, overseeing, and reviewing [32]. In general, metacognitive improves the learning outcome [67]. A BL environment supports to enhance planning, overseeing, and reviewing with the support of learning management systems. In the online environment, metacognition has a significant impact than intelligence in learning outcomes [54]. Positive emotions positively impact metacognitive strategies and a strong relationship between motive and metacognitive strategies [54]. Internet self-efficacy has high metacognitive self-regulation [69]. Metacognitive strategies enhance critical thinking [70]. Metacognitive skills-based online components show relatively effective outcomes on the learner's result [71]. The integration of metacognitive skills in the online module can improve the outcomes of BL [71]. However, not all the students show positive outcomes because of individual differences [71]. However, the challenge is in the blended context not being able to recognize the cognitive and metacognitive strategies [54].

C. MOTIVATIONAL

One of the most analysed factors related to SRL is motivation. BL motivates learners with the support of face-to-face and online learning [72]. Motivation is strongly connected to self-regulation. Self-efficacy, goal setting, and task orientation are a subdivision of motivational strategies [32]. Self-motivation and intrinsic and extrinsic goals are cornerstones for any kind of learning [43]. Growth mindset, intrinsic motivation [45], and self-effectiveness influence motivation. Chinese middle school boys have more instinctive motivation than girls [46]. On the other hand, girls are more toward following the rules and more in external motivation than boys [46]. Female stu-

dents were more dependent on the assessment of others than males [46]. In contrast, another study argues motivation and intrinsic value and motivation do not impact programming learning outcomes [34].

Students who achieve high results show high levels of motivation, self-regulation, interest, self-efficacy, and interest [52]. Mindset plays a crucial role in the application of SRL strategies. Hong Kong students show comparatively high self-efficacy and growth mindsets and have low motivation in English writing [52]. BL environment with technology improves the motivation for learning foreign languages [73]. Open badges intensely impact motivation [74].

Self-efficacy positively impacts learning outcomes [43], [46] and relates to the programming learning outcome [67]. Internet self-efficacy positively impacts Self-regulation [69]. Male students show higher capabilities in digital technology than females but do not have a significant impact on internet self-efficacy [69]. Age does not impact on internet self-efficacy [69]. However, most of the studies utilize questionnaire data for the study. Hence, in the future mixed-method study is needed to test SRL and internet self-efficacy [69].

D. RESOURCE MANAGEMENT STRATEGY

Management strategies are grouped into peer, environment, and efforts [32]. Diverse studies learn about different resource management strategies such as peer learning, environmental, platform, and instructor support. Peer learning plays a critical role in BL by collaborating and uplifting each other [2]. The challenging part of peer learning is social loafing. In the BL environment to overcome social loafing and accelerate the entire participation [1] learners can clusters based on learning capability [2]. Furthermore, the learner's prior expertise influence positively impacts the outcomes [2]. However, in a different study, researchers observed that students point out that when they choose their peers in group discussions, they can achieve more than when the teacher creates groups [78]. Instructor support means the extent to which learners trust in the value of their mentor and establish their relationship. Instructor support strongly motivates the learners [44] and influence behaviour, strategy, and involvement [44]. Instructor support positively impacts behavioral and cognitive but not the impact of emotional engagement [44]. A stable learning environment with rich learning materials positively impacts learning [13].

E. SELF-REGULATION IN GENERAL

Several researchers have investigated SRL strategies in general [56], [75]. Most of the studies reported that SRL positively impacts the learning outcomes in the BL environment [43], [46], [56] and that BL boosts SRL [58]. High self-regulated learners have more positive outcomes than low self-regulated learners [56]. In self-regulation, personal attributes impact more than environmental factors [44]. Some studies argued that gender impacts SRL, where female stu-

dents show higher self-regulation than male students while several other studies point out that gender and age do not impact self-regulation [69].

Learning mode impacts the learning process and advances learning capability [57]. The rich learning resources available online motivate SRL in BL environments [66]. The learning environment, self-regulation, and reflective instruments make students aware of their learning [58]. The effectiveness of BL depends on the learning support assistance [13]. Zhou et.al [13] identified that the learning support system for BL needs to support resources, environment, personnel, and teaching methods. For undergraduate students, SRL with class projects and design projects enhances the chances of getting a good quality internship [76]. For the category learners, BL motivates independent learning and trains self-regulation. SRL supports learning in the working environment too. Silva et al. [57] argued that traditional classroom settings for accounting do not support lifelong learning and do not develop metacognitive skills. Experienced accounting teachers are adept in their discipline and pedagogically less proficient in the improvement of metacognitive skills [57].

Blended design-based learning (bDBL) facilitated student-centred learning and self-regulated learning [77]. Among Chinese middle school students' intrinsic motivation, self-efficacy, and test anxiety are high as per a prior study [46]. Also, a study indicated that demographic characteristics play a role in self-regulation, motivation, and self-efficacy [46]. In the first-tier city, self-regulation is higher than in developing areas [46]. SRL is the cornerstone for teaching, but the focus of SRL practices in teaching education is very limited. Though some researchers tried to learn about the training teachers' college students' SRL and their impact [38], [78] in the future researchers need to focus on teachers' education curriculum in terms of SRL and its practices.

The application of flipped classrooms is less common in school. A flipped classroom can improve critical thinking and problem-solving [55]. Jiang and Jong [7] did a case study in the flipped classroom environment using a postgraduate course and concluded that instructors need to add additional activities to support self-preparation and that this should be supported by the school administration to get the intended outcomes. Here, it is identified that even postgraduate students face challenges in self-regulation in the pre-class work [7]. Furthermore, if the learning materials are hard to understand even though students apply the best SRL strategies, quality learning hardly happens [7]. Flipped classrooms using MOOC improve learning satisfaction which improves interest and self-regulation in learning [79].

As mentioned above, this study observed several practical implications for educational institutions, administrators, academics, and learners. For example, stable learning environments, rich learning resources, and learning support assistance positively impact on learning. Thus, educational institutions, administrators, and academics can work together

to enhance these features (findings of this study) by preparing guidelines and conducting training workshops on learning content and assessment preparation in digital learning environments.

VI. RESEARCH GAPS AND FUTURE DIRECTIONS

Even though there are several research studies about SRL, still there are some research gaps and limitations. First, there is a dearth of comparative studies. For example, most of the studies targeted a particular population, media literacy skills [56], narrative writing, English language learning [80], and accounting [57] or based on a particular country or educational institution [81]. This creates challenges in generalizing the findings. It is necessary to start cross-cultural studies in the future to enhance knowledge and understand the cultural impact. Second, most of the studies utilized questionnaires and self-reported data for the study which makes changes for bias in the data. Third, studies failed to focus on the holistic view of self-regulation. In early times, most of the studies focused on the forethought and performance phase and now preference has been given to the reflection phase. Thus, it is important to consider all three phases together to get an overall view.

Fourth, the limited size of the sample can be considered as another challenge. Some studies utilized a very small sample size such as thirteen. Fifth, prior researchers faced challenges in analyzing the impact over a long time. Most of the studies observed or learned from short periods, for example, 15 weeks. Sixth, studies focused on general cognitive, and metacognitive strategies. However, there is a necessity to learn about different cognitive (rehearsal, elaboration, organization) and metacognitive strategies (planning, monitoring, evaluation) that impact on learning. Finally, some studies failed to consider learning outcomes with SRL strategies' impact. SRL was developed to describe the differentiation in the learning outcomes. Therefore, when studying the impact of SRL, care is needed about learning outcomes.

This study analyzes SRL in the BL environment. The outcome of this study indicates that SRL enhances learning outcomes and that SRL strategies can be effectively triggered in the BL environment. Studies considering SRL phases and strategies in the future studies need to focus on how different SRL strategies impact all three SRL phases. Most of the studies use the questionnaire as a research instrument, hence, future researchers need to integrate self-reported data with learning system data to get a better understanding of self-regulation in the BL environment. Furthermore, most of the studies analyse SRL strategies for a particular context, therefore, there is a challenge in generalising the findings. So, in the future researchers can focus on a broader context for the study. For example, considering Science, Technology, Engineering, and Mathematics (STEM) and non-STEM learners. In the future researchers can work on an SRL model that best fits the BL. Similarly, to analyse the long-term impact of SRL, researchers can analyze the learners' SRL strategies throughout the academic period by providing different sup-

ports. Moreover, researchers can focus on how different set of students change their SRL strategies for a module with different learning supports as a longitudinal study. Also, researchers can focus on learning analytics to understand the learners' SRL strategies.

VII. CONCLUSION

Technology enhancement introduces blended learning as a new norm of education with a combination of online and face-to-face learning environments for learners. BL demands high self-regulation among the learners, while SRL is a student's ability to learn alone. This study investigated the 66 papers published between 2016 and 2024 (till March) in Scopus, IEEE Xplore, Google Scholar, and ScienceDirect databases to identify the SRL strategy used in BL and its impact on SRL in BL. In recent times, researchers' interest in SRL and BL has shown an increasing trend. However, very few researchers worked collaboratively and shared common research interests. Most of the studies utilized the questionnaire as a research instrument for their study. Most of the studies focused on undergraduate learners.

TEL and SRL facilitate personalized learning with a wide range of resources with learner control. Self-regulation leverages planning, performance, and reflection of SRL. Cognitive, metacognitive, motivational, and resource management strategies enhance the SRL in TEL. In general, most of the studies point out that SRL strategies positively impact learning outcomes. However, there are outcomes with mixed results. Furthermore, some strategies have a positive impact (e.g., self-efficacy) while some do not. BL improves the SRL with the experience of the learner and the learning environment influences learners' motivation to engage and perform. Researchers categorized the strategies under cognitive, metacognitive, motivational, and research management strategies. Understanding these strategies helps to design and deliver a better pedagogy. Most of the studies used Pintrich's MSLQ [29] to analyze the SLR in BL and confirm its consistency and validity.

The limitations of this study are as follows. This study focused on literature from 2016 and before March 2024. That is, the articles published before 2016 and after March 2024 have not been included. Next, this study utilized four selected databases to collect the articles which limited the number of publications selected for the study. Despite being regarded as the primary databases, some studies may have been overlooked. Further, the gray literature that was considered for the study was limited.

Through this study it is identified that most of the studies focused on a particular context; therefore, generalization of its result is challenging. Also, researchers used self-reported data for their study, and it is difficult to ensure, the reliability of the data. Moreover, researchers failed to analyse the impact of BL and SRL in the long term. This study suggests that in future researchers need to focus on the long-term impact of SRL and how SRL improves with time. Furthermore,

researchers can integrate the interview and learning environment log data with self-reported data to get a clearer idea.

REFERENCES

- [1] R. A. Rasheed, A. Kamsin, and N. A. Abdullah, "An approach for scaffolding students peer-learning self-regulation strategy in the online component of blended learning," *IEEE Access*, vol. 9, pp. 30721–30738, 2021, doi: [10.1109/ACCESS.2021.3059916](https://doi.org/10.1109/ACCESS.2021.3059916).
- [2] M. Uzair, U. Hassan, I. Parveen, and J. D. Souza, "Self-regulation and peer collaboration among students of higher education in digital learning space: A systematic literature review of JCR high impact factor," *Social Sci.*, vol. 10, pp. 1–10, Mar. 2023, doi: [10.20944/preprints202303.0113.v1](https://doi.org/10.20944/preprints202303.0113.v1).
- [3] Ş. Hunutlu, "Self-regulation strategies in online EFL/ESL learning: A systematic review," *Stud. Self-Access Learn. J.*, vol. 14, no. 2, pp. 136–166, Jun. 1, 2023, doi: [10.37237/140203](https://doi.org/10.37237/140203).
- [4] K. Sutherland, G. Brock, M. J. de Villiers Scheepers, P. M. Milliar, S. Norman, T. Ströhfeldt, T. Downer, N. Masters, and A. L. Black, "Non-traditional students' preferences for learning technologies and impacts on academic self-efficacy," *J. Comput. Higher Educ.*, vol. 36, no. 2, pp. 298–319, Aug. 2024, doi: [10.1007/s12528-023-09354-5](https://doi.org/10.1007/s12528-023-09354-5).
- [5] B. J. Zimmerman, "Becoming a self-regulated learner: Which are the key subprocesses?" *Contemporary Educ. Psychol.*, vol. 11, pp. 1–25, Jun. 1986.
- [6] M.-H. Cho and D. Shen, "Self-regulation in online learning," *Distance Educ.*, vol. 34, no. 3, pp. 290–301, Nov. 2013, doi: [10.1080/01587919.2013.835770](https://doi.org/10.1080/01587919.2013.835770).
- [7] Y.-C. Jiang and S.-Y. Jong, "Learner preparedness in flipped classroom: A case study of a flipped postgraduate course," in *Proc. Int. Symp. Educ. Technol. (ISET)*, Aug. 2020, pp. 57–61, doi: [10.1109/ISET49818.2020.00022](https://doi.org/10.1109/ISET49818.2020.00022).
- [8] L. Barnard, W. Y. Lan, Y. M. To, V. O. Paton, and S.-L. Lai, "Measuring self-regulation in online and blended learning environments," *Internet Higher Edu.*, vol. 12, no. 1, pp. 1–6, Jan. 2009, doi: [10.1016/j.iheduc.2008.10.005](https://doi.org/10.1016/j.iheduc.2008.10.005).
- [9] D. Bylieva, J.-C. Hong, V. Lobatyuk, and T. Nam, "Self-regulation in E-learning environment," *Educ. Sci.*, vol. 11, no. 12, p. 785, Dec. 2021, doi: [10.3390/educsci11120785](https://doi.org/10.3390/educsci11120785).
- [10] R. F. Kizilcec, M. Pérez-Sanagustín, and J. J. Maldonado, "Self-regulated learning strategies predict learner behavior and goal attainment in massive open online courses," *Comput. Educ.*, vol. 104, pp. 18–33, Jan. 2017, doi: [10.1016/j.compedu.2016.10.001](https://doi.org/10.1016/j.compedu.2016.10.001).
- [11] M. M. Elaish, L. Shuib, N. A. Ghani, and E. Yadegaridehkordi, "Mobile English language learning (MELL): A literature review," *Educ. Rev.*, vol. 71, no. 2, pp. 257–276, Mar. 2019, doi: [10.1080/00131911.2017.1382445](https://doi.org/10.1080/00131911.2017.1382445).
- [12] D. Xu and S. S. Jaggars, "The effectiveness of distance education across Virginia's community colleges: Evidence from introductory college-level math and English courses," *Educ. Eval. Policy Anal.*, vol. 33, no. 3, pp. 360–377, Sep. 2011, doi: [10.3102/0162373711413814](https://doi.org/10.3102/0162373711413814).
- [13] F. Zhou, C. Zhao, Z. Jiang, and L. Wang, "A study on the learning support service of blended learning under the environment of online open courses," in *Proc. Int. Symp. Educ. Technol. (ISET)*, Jun. 2017, pp. 272–276, doi: [10.1109/ISET.2017.67](https://doi.org/10.1109/ISET.2017.67).
- [14] M. Versteijlen and A. E. J. Wals, "Developing design principles for sustainability-oriented blended learning in higher education," *Sustainability*, vol. 15, no. 10, p. 8150, May 2023, doi: [10.3390/su15108150](https://doi.org/10.3390/su15108150).
- [15] S. Van Laer and J. Elen, "In search of attributes that support self-regulation in blended learning environments," *Educ. Inf. Technol.*, vol. 22, no. 4, pp. 1395–1454, Jul. 2017, doi: [10.1007/s10639-016-9505-x](https://doi.org/10.1007/s10639-016-9505-x).
- [16] S. Van Laer, *In Search of Attributes That Support Self-Regulation in Blended Learning Environments*. Cham, Switzerland: Springer, 2017. Accessed: Apr. 16, 2024. [Online]. Available: <https://link.springer.com/article/10.1007/s10639-016-9505-x>
- [17] S. Heikkinen, M. Saqr, and J. Malmberg, *Supporting Self-Regulated Learning With Learning Analytics Interventions—A Systematic Literature Review*. Cham, Switzerland: Springer, 2023. Accessed: Apr. 16, 2024. [Online]. Available: <https://link.springer.com/article/10.1007/s10639-022-11281-4>
- [18] C.-L. Lai and G.-J. Hwang, "Strategies for enhancing self-regulation in e-learning: A review of selected journal publications from 2010 to 2020," *Interact. Learn. Environ.*, vol. 31, no. 6, pp. 3757–3779, Aug. 2023, doi: [10.1080/10494820.2021.1943455](https://doi.org/10.1080/10494820.2021.1943455).
- [19] A. Bandura, "Self-efficacy: Toward a unifying theory of behavioral change," *Adv. Behav. Res. Therapy*, vol. 1, no. 4, pp. 139–161, Jan. 1978, doi: [10.1016/0146-6402\(78\)90002-4](https://doi.org/10.1016/0146-6402(78)90002-4).
- [20] M. Boekaerts, "Emotions, emotion regulation, and self-regulation of learning," in *Handbook of Self-Regulation of Learning and Performance*, no. 13109. U.K.: Routledge, 2015, doi: [10.4324/9780203839010.ch26](https://doi.org/10.4324/9780203839010.ch26).
- [21] X. Tao, H. Hanif, and N. A. Ebrahim, "Emerging trends of self-regulated learning: A comprehensive bibliometric analysis," *World J. English Lang.*, vol. 13, no. 6, p. 252, Jun. 2023, doi: [10.5430/wjel.v13n6p252](https://doi.org/10.5430/wjel.v13n6p252).
- [22] E. Panadero, "A review of self-regulated learning: Six models and four directions for research," *Frontiers Psychol.*, vol. 8, pp. 1–28, Apr. 2017, doi: [10.3389/fpsyg.2017.00422](https://doi.org/10.3389/fpsyg.2017.00422).
- [23] M. Boekaerts, "Motivated learning: Bias in appraisals," *Int. J. Educ. Res.*, vol. 12, no. 3, pp. 267–280, Jan. 1988.
- [24] A. Efklides, "Interactions of metacognition with motivation and affect in self-regulated learning: The MASRL model," *Educ. Psychologist*, vol. 46, no. 1, pp. 6–25, Jan. 2011, doi: [10.1080/00461520.2011.538645](https://doi.org/10.1080/00461520.2011.538645).
- [25] B. J. Zimmerman, "From cognitive modeling to self-regulation: A social cognitive career path," *Educ. Psychologist*, vol. 48, no. 3, pp. 135–147, Jul. 2013, doi: [10.1080/00461520.2013.794676](https://doi.org/10.1080/00461520.2013.794676).
- [26] B. J. Zimmerman, "A social cognitive view of self-regulated academic learning," *J. Educ. Psychol.*, vol. 81, no. 3, pp. 329–339, Sep. 1989, doi: [10.1037/0022-0663.81.3.329](https://doi.org/10.1037/0022-0663.81.3.329).
- [27] F. G. Hartmann, D. Mouton, and B. Ertl, "The big six interests of STEM and non-STEM students inside and outside of teacher education," *Teaching Teacher Edu.*, vol. 112, Apr. 2022, Art. no. 103622, doi: [10.1016/j.tate.2021.103622](https://doi.org/10.1016/j.tate.2021.103622).
- [28] A. F. Hadwin, M. Oshige, C. L. Z. Gress, and P. H. Winne, "Innovative ways for using gStudy to orchestrate and research social aspects of self-regulated learning," *Comput. Hum. Behav.*, vol. 26, no. 5, pp. 794–805, Sep. 2010, doi: [10.1016/j.chb.2007.06.007](https://doi.org/10.1016/j.chb.2007.06.007).
- [29] P. R. Pintrich, D. A. F. Smith, T. Garcia, and W. J. McKeachie, "Reliability and predictive validity of the motivated strategies for learning questionnaire (Mslq)," *Educ. Psychol. Meas.*, vol. 53, no. 3, pp. 801–813, Sep. 1993, doi: [10.1177/0013164493053030204](https://doi.org/10.1177/0013164493053030204).
- [30] V. S. G. Silverajah, S. L. Wong, A. Govindaraj, M. N. Khambari, R. W. B. O. K. Rahmat, and A. R. M. Deni, "A systematic review of self-regulated learning in flipped classrooms: Key findings, measurement methods, and potential directions," *IEEE Access*, vol. 10, pp. 20270–20294, 2022, doi: [10.1109/ACCESS.2022.3143857](https://doi.org/10.1109/ACCESS.2022.3143857).
- [31] S. Heikkinen, M. Saqr, J. Malmberg, and M. Tedre, "Supporting self-regulated learning with learning analytics interventions—A systematic literature review," *Educ. Inf. Technol.*, vol. 28, no. 3, pp. 3059–3088, Mar. 2023, doi: [10.1007/s10639-022-11281-4](https://doi.org/10.1007/s10639-022-11281-4).
- [32] J. H. Eggers and J. Voogt, "Self-regulation strategies in blended learning environments in higher education: A systematic review," *Australas. J. Educ. Technol.*, vol. 37, no. 6, pp. 175–192, 2021.
- [33] Y. Shi, S. Wang, Y. Ma, J. MacLeod, and H. H. Yang, "College students' learning outcomes in flipped classroom instruction: A literature review," in *Proc. Int. Symp. Educ. Technol.*, Sep. 2018, pp. 78–81, doi: [10.1109/ISET.2018.00026](https://doi.org/10.1109/ISET.2018.00026).
- [34] L. Silva, A. Mendes, A. Gomes, G. Fortes, C. T. Lam, and C. Chan, "Exploring the association between self-regulation of learning and programming learning: A multinational investigation," in *Proc. IEEE Frontiers Educ. Conf.*, Oct. 2021, pp. 1–8. [Online]. Available: <https://www.researchgate.net/publication/356092190>
- [35] L. Su, N. Noordin, and J. J. Jeyaraj, "Effectiveness of self-regulated learning intervention on foreign language learning at tertiary level: A systematic review," *World J. English Lang.*, vol. 13, no. 5, pp. 403–411, Apr. 2023, doi: [10.5430/wjel.v13n5p403](https://doi.org/10.5430/wjel.v13n5p403).
- [36] B. Boyer and E. Dziedzic-Elliott, "What I had, what I needed: First-year students reflect on how their high school experience prepared them for college research," *J. Acad. Librarianship*, vol. 49, no. 4, Jul. 2023, Art. no. 102742, doi: [10.1016/j.acalib.2023.102742](https://doi.org/10.1016/j.acalib.2023.102742).
- [37] M. J. Page, J. E. McKenzie, P. M. Bossuyt, I. Boutron, T. C. Hoffmann, C. D. Mulrow, L. Shamseer, J. M. Tetzlaff, E. A. Akl, S. E. Brennan, and R. Chou, "The PRISMA 2020 statement: An updated guideline for reporting systematic reviews," *BMJ*, vol. 372, p. 71, Mar. 29, 2020, doi: [10.1136/bmj.n71](https://doi.org/10.1136/bmj.n71).

- [38] K. Oddone, "The nature of teachers' professional learning through a personal learning network: Individual, social and digitally connected," *Teaching Teacher Educ., Leadership Prof. Develop.*, vol. 1, Dec. 2022, Art. no. 100001, doi: [10.1016/j.tatep.2022.100001](https://doi.org/10.1016/j.tatep.2022.100001).
- [39] I. Ruthotto, Q. Kreth, J. Stevens, C. Trively, and J. Melkers, "Lurking and participating in the virtual classroom: The effects of gender, race, and age among graduate students in computer science," *Comput. Educ.*, vol. 151, Jul. 2020, Art. no. 103854, doi: [10.1016/j.compedu.2020.103854](https://doi.org/10.1016/j.compedu.2020.103854).
- [40] C. Dziuban, C. R. Graham, P. D. Moskal, A. Norberg, and N. Sicilia, "Blended learning: The new normal and emerging technologies," *Int. J. Educ. Technol. Higher Educ.*, vol. 15, no. 1, pp. 1–16, Dec. 2018, doi: [10.1186/s41239-017-0087-5](https://doi.org/10.1186/s41239-017-0087-5).
- [41] N. M. Andreeva, I. P. Artyukhov, E. G. Myagkova, N. I. Pak, and Z. K. Akkasynova, "Organizing blended learning for students on the basis of learning roadmaps," *J. Social Stud. Educ. Res.*, vol. 9, no. 2, pp. 47–64, 2018. [Online]. Available: <http://www.jsser.org>
- [42] P. Nuankaew, D. Teeraputon, W. Nuankaew, K. Phanniphong, S. Imwut, and S. Bussaman, "Perception and attitude toward self-regulated learning in educational data mining," in *Proc. 6th Int. Conf. Tech. Educ.*, Mar. 2019, pp. 1–5.
- [43] H. Falfushynska, A. Klos-Witkowska, B. Buyak, G. Tereshchuk, U. Iatsykovska, P. Falat, and R. Szklarczyk, "The development of distance learning in Ukrainian liberal arts institutions based on EU experience," in *Proc. Inst. Elect. Electron. Eng., 10th IEEE Int. Conf. Intell. Data Acquisition Adv. Comput. Syst.*, Metz, France, Sep. 2019, pp. 24–27.
- [44] X. Zhao, X. Wang, Y. Wei, J. Wang, J. Tian, and C. Zuo, "Research on the influence of college students' engagement in blended learning: Teacher support, situational interest, and self-regulation," in *Proc. Int. Symp. Educ. Technol.*, Aug. 2020, pp. 170–174, doi: [10.1109/ISET49818.2020.00045](https://doi.org/10.1109/ISET49818.2020.00045).
- [45] C. Stöhr and K. Färnevik, "May online blended learning in corporate training enhance lifelong learning? Experiences from artificial intelligence courses for professionals," in *Proc. IEEE Frontiers Educ. Conf. (FIE)*, Oct. 2020, pp. 1–5, doi: [10.1109/FIE44824.2020.9274213](https://doi.org/10.1109/FIE44824.2020.9274213).
- [46] Z. X. Huang, S. Li, J. L. Du, Y. Pei, and X. P. Tang, "Status quo of Chinese middle school students' self-regulated learning and its impact on the academic performance of blended learning," in *Proc. 9th Int. Conf. Educ. Innov. Technol.*, Dec. 2020, pp. 148–153, doi: [10.1109/EITT50754.2020.00033](https://doi.org/10.1109/EITT50754.2020.00033).
- [47] J. K. L. Leung, S. K. W. Chu, T.-C. Pong, D. T. K. Ng, and S. Qiao, "Developing a framework for blended design-based learning in a first-year multidisciplinary design course," *IEEE Trans. Educ.*, vol. 65, no. 2, pp. 210–219, May 2022, doi: [10.1109/TE.2021.3112852](https://doi.org/10.1109/TE.2021.3112852).
- [48] I. Evangelista, F. Nardoni, and M. Cadierno, "Flipping the high-school classroom: Contributions for learning in a case study," in *Proc. World Eng. Educ. Forum—Global Eng. Deans Council (WEEF-GEDC)*, Albuquerque, NM, USA, 2018, pp. 1–5, doi: [10.1109/WEEF-GEDC.2018.8629637](https://doi.org/10.1109/WEEF-GEDC.2018.8629637).
- [49] R. Y. Ng, R. Y. Lam, K.-K. Ng, and I. K. Lai, "A study of vocational and professional education and training (VPET) students and Teachers' preferred support for technology based blended learning," in *Proc. Int. Symp. Educ. Technol. (ISET)*, Jun. 2017, pp. 268–271, doi: [10.1109/ISET.2017.66](https://doi.org/10.1109/ISET.2017.66).
- [50] J. L. Jensen, E. A. Holt, J. B. Sowards, T. H. Ogden, and R. E. West, "Investigating strategies for pre-class content learning in a flipped classroom," *J. Sci. Educ. Technol.*, vol. 27, no. 6, pp. 523–535, Dec. 2018, doi: [10.1007/s10956-018-9740-6](https://doi.org/10.1007/s10956-018-9740-6).
- [51] U. K. Masrom, N. A. N. M. Alwi, and N. H. N. Asshidin, "The underlying factors of learner readiness and satisfaction in blended learning environment," in *Proc. 6th IEEE Int. Conf. MOOCs Innov. Technol. Educ., IEEE Educ. Soc., Inst. Elect. Electron. Eng.*, Hyderabad, India, Nov. 2018, pp. 69–73.
- [52] B. Bai and W. Guo, "Motivation and self-regulated strategy use: Relationships to primary school students' English writing in Hong Kong," *Lang. Teach. Res.*, vol. 25, no. 3, pp. 378–399, May 2021, doi: [10.1177/1362168819859921](https://doi.org/10.1177/1362168819859921).
- [53] B. A. Chun and H. J. Heo, "The effect of flipped learning on academic performance as an innovative method for overcoming ebbinghaus' forgetting curve," in *Proc. ACM Int. Conf. Assoc. Comput. Machinery*, Jan. 2018, pp. 56–60, doi: [10.1145/3178158.3178206](https://doi.org/10.1145/3178158.3178206).
- [54] E. Acosta-Gonzaga and A. Ramirez-Arellano, "The influence of motivation, emotions, cognition, and metacognition on students' learning performance: A comparative study in higher education in blended and traditional contexts," *SAGE Open*, vol. 11, no. 2, Apr. 2021, Art. no. 215824402110275, doi: [10.1177/21582440211027561](https://doi.org/10.1177/21582440211027561).
- [55] R. M. Dianty, Y. Yurniwati, I. Lestari, and A. Manahor, "The effect of flipped classroom based on team games tournament on mathematics problem-solving ability," *Psychol., Eval., Technol. Educ. Res.*, vol. 5, no. 2, pp. 106–118, Jun. 2023, doi: [10.33292/petier.v5i2.170](https://doi.org/10.33292/petier.v5i2.170).
- [56] M. Rais, R. Fadillah, and A. A. Rivai, "The effectiveness of blended learning in improving media literacy on different self-regulated learning," *J. Educ. Sci. Technol. (EST)*, vol. 5, pp. 277–285, Dec. 2019, doi: [10.26858/est.v5i3.10873](https://doi.org/10.26858/est.v5i3.10873).
- [57] T. B. de Jesus Silva, L. A. Lay, N. Hein, V. T. Biavatti, and V. C. da Silva Zonatto, "Self-regulated learning (SRL) strategies in distance education in accounting," *Revista Educação Pesquisa Contabilidade*, vol. 11, no. 1, p. 89, Jan. 2017. [Online]. Available: <https://search.ebscohost.com/login.aspx?direct=true&profile=ehost&scope=site&authtype=crawler&jrnl=19818610&AN=122751356&h=Mr%2F%2FMc%2B6HZF4TYSKv977qeAW41P%2BtkqphkW%2Bg2T5JiOL%2B1%2FgeAWwVHVMaFWMU23NNOUHWvMDKClJ2aQhQQyoA%3D%3D&crl=c>
- [58] *Moscow Power Engineering Institute and Institute of Electrical and Electronics Engineers*, Moscow Power Eng. Inst., Moscow, Russia, Apr. 2020.
- [59] N. Sugrah and A. Wiyarsi, "An exploration of FCM's impact on students' perceptions of support, self-regulated learning, and critical thinking," *Int. J. Inf. Educ. Technol.*, vol. 13, no. 3, pp. 496–504, Mar. 2023, doi: [10.18178/ijiet.2023.13.3.1831](https://doi.org/10.18178/ijiet.2023.13.3.1831).
- [60] T. A. Baranova, E. Y. Tokareva, A. M. Kobicheva, and N. G. Olkhovik, "Effects of an integrated learning approach on students' outcomes in St. Petersburg polytechnic university," in *Proc. 3rd Int. Conf. Digit. Technol. Educ.*, vol. 170, Oct. 2019, pp. 77–81, doi: [10.1145/3369199.3369245](https://doi.org/10.1145/3369199.3369245).
- [61] M. Abdullah, "Reading speed and comprehension enhancement in hybrid learning delivery mode," *Adv. Lang. Literary Stud.*, vol. 9, no. 3, p. 25, Jun. 2018, doi: [10.7575/aiac.all.v9n.3p.25](https://doi.org/10.7575/aiac.all.v9n.3p.25).
- [62] J. R. Martínez-Fernández, I. Noguera-Fructuoso, A. Ciraso-Calí, and A. Vega-Martínez, "Estudio exploratorio sobre los perfiles de regulación y la satisfacción con el aula invertida en estudiantes universitarios," *Revista Española de Pedagogía*, vol. 82, no. 287, Jan. 2024, doi: [10.22550/2174-0909.3931](https://doi.org/10.22550/2174-0909.3931).
- [63] W. Chen, J. S. H. Tan, and Z. Pi, "The spiral model of collaborative knowledge improvement: An exploratory study of a networked collaborative classroom," *Int. J. Comput.-Supported Collaborative Learn.*, vol. 16, no. 1, pp. 7–35, Mar. 2021, doi: [10.1007/s11412-021-09338-6](https://doi.org/10.1007/s11412-021-09338-6).
- [64] L. Zheng, L. Zhong, and Y. Fan, "An immediate analysis of the interaction topic approach to promoting group performance, knowledge convergence, cognitive engagement, and coregulation in online collaborative learning," *Educ. Inf. Technol.*, vol. 28, no. 8, pp. 9913–9934, Aug. 2023, doi: [10.1007/s10639-023-11588-w](https://doi.org/10.1007/s10639-023-11588-w).
- [65] J. Zhou and J.-M. Ye, "Investigating cognitive engagement patterns in online collaborative learning: A temporal learning analytic study," *Interact. Learn. Environ.*, pp. 1–17, Jan. 2024, doi: [10.1080/10494820.2023.2299976](https://doi.org/10.1080/10494820.2023.2299976).
- [66] N. Venkatarayalu, "E-learning resources for improving student achievement in a course on RF engineering," in *Proc. IEEE Int. Conf. Teaching, Assessment, Learn. Eng. (TALE)*, Dec. 2020, pp. 688–691, doi: [10.1109/TALE48869.2020.9368425](https://doi.org/10.1109/TALE48869.2020.9368425).
- [67] L. Silva, A. Mendes, A. Gomes, G. Fortes, C. T. Lam, and C. Chan, "Exploring the association between self-regulation of learning and programming learning: A multinational investigation," in *Proc. IEEE Frontiers Educ. Conf.*, Oct. 2024, pp. 1–8. [Online]. Available: <https://ieeexplore.ieee.org/abstract/document/9637438/>
- [68] C. Stock, R. D. O. Dev, K. G. Soh, N. J. M. Nasiruddin, Y. Yuan, and X. Ji, "Blended learning in physical education: A systematic review," *Frontiers Public Health*, vol. 11, Mar. 2023, Art. no. 1073423.
- [69] Y.-C. Kuo, H. W. Tseng, and Y.-T. Kuo, "Internet self-efficacy, self-regulation, and student performance: African-American adult students in online learning," *J. E-Learn.*, vol. 19, pp. 161–180, Apr. 2022. [Online]. Available: <https://www.researchgate.net/publication/339831231>
- [70] E. Nusantari, A. Abdul, I. Damopolli, A. S. R. Alghafri, and B. S. Bakkar, "Combination of discovery learning and metacognitive knowledge strategy to enhance students' critical thinking skills," *Eur. J. Educ. Res.*, vol. 10, no. 4, pp. 1781–1791, Oct. 2021, doi: [10.12973/eu-jer.10.4.1781](https://doi.org/10.12973/eu-jer.10.4.1781).
- [71] T. A. Rini, S. Akbar, R. D. T. Maningtyas, and B. Cahyanto, "The effectiveness of E-module through metacognitive construction in blended learning system," in *Proc. 6th Int. Conf. Educ. Technol. (ICET)*, Oct. 2020, pp. 1–6, doi: [10.1109/ICET51153.2020.9276588](https://doi.org/10.1109/ICET51153.2020.9276588).

- [72] S. H. Karunanayaka and B. Sheehan. *E Cases of Digitizing Higher Education—A Global Perspective*. Accessed: Feb. 24, 2024. [Online]. Available: <https://contessa-project.eu/>
- [73] L. R. Nizamieva, G. I. Nazarova, E. K. Kuzmina, and G. Broussois, “Model of the organization of the blended learning in the translation of business correspondence on the basis of electronic educational resources,” *Int. J. Innov. Technol. Exploring Eng.*, vol. 9, no. 1, pp. 5134–5137, Nov. 2019, doi: [10.35940/ijitee.A9214.119119](https://doi.org/10.35940/ijitee.A9214.119119).
- [74] I. Buchem and O. B. Gené. *Motivational Effects of Open Badges in MOOCs. A Learner Perception Study in OpenVM Learning Hub and MiriadaX*. Accessed: Apr. 16, 2024. [Online]. Available: <https://cejsh.icm.edu.pl/cejsh/element/bwmeta1.element.desklight-ef23aa30-bbb4-4cd4-81ca-4259f5ac98a3>
- [75] T. Türkbën, “The effect of self-regulated strategy education on the writing skills of middle school students,” *Int. J. Educ. Literacy Stud.*, vol. 9, no. 2, p. 52, May 2021, doi: [10.7575/aiac.ijels.v.9n.2p.52](https://doi.org/10.7575/aiac.ijels.v.9n.2p.52).
- [76] A. Raza and M. Hasib, “Digital transformation of education toward successful internships: A methodology developed over seven years and tested during COVID-19,” *IEEE Trans. Educ.*, vol. 66, no. 3, pp. 244–253, Jun. 2022, doi: [10.1109/TE.2022.3221842](https://doi.org/10.1109/TE.2022.3221842).
- [77] J. K. L. Leung and P. D. Lavigne, “Blended design-based learning (bDBL), an innovative approach to cornerstone engineering design,” in *Proc. IEEE Int. Conf. Eng., Technol. Educ.*, Dec. 2019, pp. 1–7.
- [78] M. Mackey, S. V. Drew, J. Nicoll-Senft, and L. Jacobson, “Advancing a theory of change in a collaborative teacher education program innovation through universal design for learning,” *Social Sci. Humanities Open*, vol. 7, no. 1, 2023, Art. no. 100468, doi: [10.1016/j.ssaho.2023.100468](https://doi.org/10.1016/j.ssaho.2023.100468).
- [79] P. Li, L. Meng, and H. Huang, “Application of flipped classroom teaching mode based on MOOC concept in surgical nursing teaching,” in *Proc. Int. Conf. Inf. Sci. Educ. (ICISE-IE)*, Dec. 2020, pp. 630–633, doi: [10.1109/ICISE51755.2020.00141](https://doi.org/10.1109/ICISE51755.2020.00141).
- [80] O. N. Brega and G. V. Kruglyakova, “Students’ readiness to online English language self-learning module and approaches to its integration into the educational process,” *Perspect. Sci. Educ.*, vol. 57, no. 3, pp. 311–323, Jul. 2022, doi: [10.32744/pse.2022.3.17](https://doi.org/10.32744/pse.2022.3.17).
- [81] R. Çobanoğlu, S. Büyükkidik, and G. D. Y. Kumlu, “A bibliometric analysis of research on self-regulated learning: From the beginning to 2021,” *J. Theor. Educ. Sci.*, vol. 16, no. 3, pp. 700–726, Jul. 2023, doi: [10.30831/akukeg.1225513](https://doi.org/10.30831/akukeg.1225513).



M. S. FAATHIMA FAYAZA (Member, IEEE) received the bachelor’s degree in information technology and the M.Sc. degree in computer science, specializing in data science engineering and analytics from the University of Moratuwa, Sri Lanka, in 2016 and 2020, respectively, where she is currently pursuing the Ph.D. degree. She is a Lecturer and the Head of the Department of Information Technology, South Eastern University of Sri Lanka, Sri Lanka. Her research interests

include e-learning systems, blended learning, personalized and adaptive learning systems, self-regulated learning, e-education, natural language processing, information systems, data science, software testing, and verification.



SUPUNMALI AHANGAMA (Senior Member, IEEE) received the Ph.D. degree in information systems from the National University of Singapore. From 2018 to 2022, she held the position of the Director of Undergraduate Studies with the Faculty of Information Technology, University of Moratuwa, Sri Lanka. She is currently a Senior Lecturer with the Department of Information Technology, University of Moratuwa. Her research interests include data science, design science, information systems, social network analysis, e-government, and e-education, among others. She received the Outstanding Associate Editor Award from ICIS 2023. She is the President of the Section E3 (Computer Science) of Sri Lanka Association for the Advancement of Science (SLAAS) and the Treasurer of the IEEE Computer Science Sri Lanka Chapter. She has presented her work and served as a Reviewer for numerous top-tier forums, including *e-Service Journal*, *IEEE ACCESS*, *Information Systems Frontiers*, *Heliyon*, *IEEE TRANSACTIONS ON ENGINEERING MANAGEMENT, IT and People*, the International Conference on Information Systems (ICIS), and Pacific Asia Conference on Information Systems (PACIS).

...