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Research Article

A cognitive–motivational model of self-regulated learning readiness: Integrating digital metacognition and academic self-efficacy in teacher professional education

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Limited studies have investigated the interplay among digital metacognition, academic self-efficacy, and self-regulated learning readiness within the Indonesian Teacher Professional Education programme, leaving the mechanisms underlying Self-Regulated Learning in digital environments insufficiently understood. The study examined the direct association of digital metacognition with Self-Regulated Learning readiness, and the mediating and moderating roles of academic self-efficacy. The study utilised a quantitative survey design, involving 462 in-service teachers enrolled in the Teacher Professional Education programme. Data were collected on digital metacognition, academic self-efficacy, and Self-Regulated Learning readiness using validated instruments and analysed using covariance-based structural equation modelling with LISREL version 8.70. The findings showed that perceived digital metacognition was positively associated with academic self-efficacy and Self-Regulated Learning readiness, while academic self-efficacy showed the strongest direct association with readiness. Academic self-efficacy also statistically mediated the relationship between digital metacognition and Self-Regulated Learning readiness. In addition, a statistically significant interaction indicated that the strength of this relationship varied according to participants' levels of academic self-efficacy. The model explained 19.2% of the variance in academic self-efficacy and 54.2% of the variance in Self-Regulated Learning readiness. The findings show the combined effect of cognitive and motivational elements on the likelihood of Self-Regulated Learning in digital professional education environments, thus extending Self-Regulated Learning Theory and Social Cognitive Theory. Practically, the research provides evidence-based insights to support the development of a Teacher Professional Education programme to support digital metacognition, academic self-efficacy, and readiness for Self-Regulated Learning.

Keywords: Academic self-efficacy; Digital metacognition; Readiness; Self-regulated learning; Teacher professional education programme

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1. Introduction

The digital transformation associated with the Fourth Industrial Revolution and the human-centred vision of Society 5.0 has reshaped teacher education by expanding the use of artificial intelligence, learning management systems, learning analytics, cloud-based resources, video-

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conferencing platforms, digital modules, online assessment systems, and online professional learning networks. Although the Fourth Industrial Revolution has been characterised by increasing automation, connectivity, and data-intensive systems, contemporary educational digitalisation increasingly requires technology to be integrated in ways that remain pedagogically purposeful, critically informed, and responsive to human and educational needs (Mnguni, 2023). This transformation has broadened teachers' professional roles beyond the operational use of digital tools to include the development of technopedagogical competence, critical engagement with emerging technologies, adaptation of pedagogical practices, and continuous professional learning (Çakır & Güner, 2026; Lazaris et al., 2026; Wohlfart & Wagner, 2023). These competencies are increasingly important because teachers' capacity to integrate emerging technologies is associated with their technological-pedagogical knowledge and readiness to adopt such tools meaningfully in educational practice (Çakır & Güner, 2026). Such demands become particularly salient in online and blended professional education, where teachers themselves assume the role of learners and must exercise considerable control over when, where, and how they learn. This requires them to set goals, organise their learning environment and time, monitor their progress, seek assistance when necessary, and adapt their strategies in response to learning demands (Arrafii et al., 2025; Feldman-Maggor et al., 2024; Hemmler & Ifenthaler, 2024). Evidence from Indonesian distance-learning contexts further highlights the importance of self-regulated learning strategies for effective participation in digitally mediated learning environments (Arrafii et al., 2025). Accordingly, successful participation in the Indonesian Teacher Professional Education programme requires more than access to digital technologies; it also requires participants to be cognitively and motivationally prepared to regulate their learning effectively in technology-mediated environments.

Digital technologies have become increasingly embedded in teacher professional education, supporting course delivery, communication, access to instructional resources, assessment, feedback, and collaborative professional learning (Langset et al., 2018; Mohafa et al., 2026). These environments may incorporate learning management systems, videoconferencing platforms, digital modules, online assessment tools, artificial intelligence-assisted applications, cloud-based resources, and professional learning networks. In particular, contemporary learning management systems can integrate automated assessment, immediate feedback, and progress-monitoring functions within the learning process (Dorji et al., 2026).

However, access to and frequent use of digital technologies do not in themselves ensure effective learning or the development of self-regulatory capacities. Meaningful participation in technology-mediated education also depends on relevant technopedagogical competencies, appropriately designed learning experiences, feedback, and supportive pedagogical conditions (Çakır & Güner, 2026; Mohafa et al., 2026). Accordingly, teachers participating in online and blended professional education must assume substantial responsibility for regulating their own learning, including setting goals, managing time and learning environments, monitoring progress, evaluating the effectiveness of learning strategies, and modifying those strategies when necessary (Arrafii et al., 2025; Feldman-Maggor et al., 2024; Hemmler & Ifenthaler, 2024).

Importantly, the expansion of digital learning opportunities should not be equated with uniformly strong self-regulated learning readiness. Evidence from Indonesian distance-learning contexts indicates considerable variation in the use of self-regulation strategies, with some strategies, particularly help-seeking, being less frequently employed than others (Arrafii et al., 2025). Moreover, online self-efficacy and self-regulated learning are meaningfully associated with learners' experiences and outcomes in online environments (Zheng & Xiao, 2024), while evidence from pre-service teacher education shows that online self-regulation can play an important role in linking self-management and self-control with academic achievement (Danişman et al., 2023). Thus, within Indonesia's Teacher Professional Education programme, effective participation requires more than technological access and operational digital skills; it also requires the cognitive,

motivational, and self-regulatory capacities needed to plan, monitor, and adapt learning in technology-mediated environments (Arrafii et al., 2025).

Self-regulated learning [SRL] in educational psychology is an active and productive process where students develop learning goals, assess progress, develop techniques and regularly reflect on learning results (Zimmerman, 2000, 2002). Self-regulated learning in digital environments involves more than general control over learning; it also requires learners to regulate their interaction with technology-mediated learning conditions, including the organization of their learning environment, management of time and distractions, strategic help-seeking, and continuous monitoring of learning progress (Arrafii et al., 2025; Deng et al., 2024; Santoso et al., 2022). These demands become particularly salient in online and distance education, where learners assume greater responsibility for organizing and monitoring their learning with less immediate external regulation (Arrafii et al., 2025; Azennoud, 2022). In the present study, SRL readiness is therefore conceptualized as the extent to which learners possess the cognitive, metacognitive, motivational, and strategic capacities required to engage independently and responsibly in technology-mediated learning.

Importantly, participation in digital learning does not necessarily imply that learners are equally prepared to regulate their learning effectively. Evidence from Indonesia indicates that online learners may experience particular difficulties with time allocation, task-strategy development, and help-seeking, even when their overall levels of online self-regulation are relatively positive (Arrafii et al., 2025; Santoso et al., 2022). Digital environments can also introduce attentional challenges through distraction and multitasking, increasing the importance of strategies for maintaining focus and regulating learning behaviour (Deng et al., 2024). Moreover, motivation, self-monitoring, and self-management are closely intertwined with the ways learners regulate their learning in online environments (Danişman et al., 2023; Zhu & Doo, 2022). Taken together, these findings suggest that readiness for self-regulated learning should not be assumed to emerge automatically from exposure to technology; rather, it depends on a combination of cognitive, metacognitive, motivational, behavioural, and strategic capacities that enable learners to manage their learning effectively in digitally mediated contexts.

Metacognition refers in general to the consciousness and regulation of his or her own thinking processes, including planning, monitoring, assessing, and regulating learning procedures (Flavell, 1979). Concerning technology-based learning, the concept of metacognition has evolved to mean digital metacognition. Students' ability to manage their cognitive processes when interacting with digital environments (Fahrni et al., 2025). Digital metacognition is the ability to organise learning activities with the help of digital resources; to supervise the understanding when engaging with multimedia; to critically evaluate the effectiveness of online learning techniques; and to adjust techniques based on the feedback received from digital systems (Susantini et al., 2021).

Learning is influenced not only by cognitive characteristics but also by motivational factors. Among these, academic self-efficacy [ASE], referring to learners' beliefs in their capability to succeed in academic tasks, represents an important motivational resource for learning (Asio, 2026). Self-efficacy influences how learners approach challenging tasks, the effort they invest, their persistence when difficulties arise, and their strategic engagement with learning activities (Aivaliotis & Emvalotis, 2026). Its role may become particularly salient in digital learning environments, where learners are expected to exercise greater independence and assume more responsibility for regulating their learning.

In technology-mediated contexts, academic self-efficacy may operate alongside more domain-specific forms of technological self-efficacy. Recent evidence indicates that academic self-efficacy is meaningfully associated with digital competence, while technology-specific self-efficacy is related to learners' literacy, attitudes, and willingness to engage with emerging digital technologies (Asio, 2025, 2026; Asio & Gadia, 2024). Learners with stronger efficacy beliefs are therefore more likely to approach challenging learning tasks with confidence, sustain effort, and employ strategies directed toward successful performance (Aivaliotis & Emvalotis, 2026). Conversely, weaker efficacy beliefs

may be associated with lower persistence and a greater tendency to disengage from demanding tasks. From this perspective, ASE may contribute to self-regulated digital learning not simply as a direct correlate of academic performance but as a motivational resource that supports the enactment of strategic and metacognitive learning processes. In digital and distance-learning environments, where learners must independently structure their environment, manage learning strategies, monitor progress, and regulate their behaviour, such motivational resources become particularly relevant (Arrafii et al., 2025). Accordingly, ASE and digital metacognitive competence may be viewed as complementary components of readiness for autonomous learning, with the former providing confidence to initiate and sustain regulation and the latter supporting the planning, monitoring, and evaluation of learning.

Although an expanding body of literature has examined digital learning, metacognition, and SE, several important gaps remain (Brunner et al., 2025; Yuan et al., 2024; Zheng & Xiao, 2024). First, previous studies have predominantly examined digital metacognition and ASE as independent predictors of learning outcomes, with limited attention to their combined influence on SE learning readiness (Alnujaidi, 2026; Saeid & Eslaminejad, 2016; Tømte & Hatlevik, 2011). Second, existing research has rarely investigated ASE as both a mediating and moderating mechanism within a single explanatory cognitive–motivational model (Fokkens-Bruinsma et al., 2021). Third, empirical evidence from teacher professional education contexts remains limited, despite the increasing importance of SE learning for prospective teachers who are expected to engage in continuous digital environments for professional learning (Brunner et al., 2025; Karlen et al., 2020). Addressing these gaps is important for advancing the understanding of SRL in digital education. Taken together, previous studies have primarily examined self-efficacy as an antecedent or mediator of self-regulated learning, while its moderating role has received comparatively limited attention and has mainly been investigated in specific learning domains (Akamatsu et al., 2019; Gentner & Seufert, 2020; Landa et al., 2025; Zheng & Xiao, 2024). Thus, whether academic self-efficacy strengthens the relationship between digital metacognition and self-regulated learning readiness remains unclear, particularly in teacher professional education.

While situated within Indonesia's Professional Teacher Education [PPG] program, this study addresses a broader international concern regarding teachers' readiness to engage in lifelong learning and continuous professional development in digital environments. As professional adult learners, PPG teachers face challenges similar to those experienced by educators worldwide, making this context relevant for increasing understanding of SRL readiness in contemporary teacher education.

The originality of this study lies in the proposed cognitive–motivational model of self-regulated learning readiness. The model integrates digital metacognition as the cognitive component and academic self-efficacy as the motivational component. Unlike previous studies that have generally examined these constructs separately or focused primarily on direct relationships, the proposed model examines academic self-efficacy as a direct predictor, statistical mediator, and moderator of the relationship between digital metacognition and self-regulated learning readiness (Bandura, 2015; Zimmerman, 2000, 2002). This study advances the literature by conceptualising ASE as both a mediating and moderating mechanism. This dual-role perspective provides a deeper explanation of how metacognitive awareness is translated into readiness for independent learning in digital environments. The study further extends SRL Theory by considering digital metacognition as a foundational cognitive antecedent of learning readiness and enriches Social Cognitive Theory by showing that ASE not only predicts learning behaviour but also supports and channels the influence of metacognitive competencies. This research integrates cognitive and motivational processes in one explanatory model and so provides a more thorough explanation of the SRL preparedness of professional teacher learners in the digital age.

2. Literature Review

The literature study is structured around the three dimensions that constitute the suggested cognitive-motivational model of self-regulated learning readiness. It begins with academic self-efficacy as the motivational concept that promotes learners' confidence, determination, and effort towards achieving academic objectives. Furthermore, it examines digital metacognition as the cognitive ability to plan, monitor, assess and control learning in technology-mediated contexts and self-regulated learning readiness as the learners' competence to manage their learning independently and responsibly. The review then synthesises empirical information on the relationships between these constructs, finds theoretical and contextual gaps in previous research and presents the justification for the suggested direct, mediating and moderating hypotheses. Building on this synthesis, the next part proposes hypotheses about the direct links among the three constructs and the mediating and moderating roles of academic self-efficacy.

2.1. Academic Self-Efficacy

Self-efficacy is what people believe they can do to organise and perform the actions needed to attain specific results (Bandura, 1997). These assumptions are domain- and task-specific, rather than a generic view of personal competence (Pajares, 1996). Consequently, individuals may have varying degrees of self-efficacy in academic, instructional, technical, and professional domains. Academic self-efficacy refers to one's confidence in the effective accomplishment of academic learning tasks. Teaching self-efficacy refers to one's confidence in the performance of instructional responsibilities. Technology self-efficacy refers to one's confidence in the operation and use of technological instruments. These areas may be connected, yet they are conceptually distinct efficacy beliefs. The present study is concerned with academic self-efficacy since the participants were studied in their capacity as professional learners engaged in academically challenging activities in the Teacher Professional Education course.

Self-Efficacy is based on Bandura's Social Cognitive Theory and refers to an individual's perception of their ability to successfully manage and complete academic assignments (Bandura, 1997). ASE influences students' objective formulation for learning, choice of learning methodologies, perseverance, and responses to academic problems in an educational context (Sutherland et al., 2024). Students with high ASE are more confident in understanding the subject, completing complicated activities, and persisting in the face of problems, all of which positively contribute to academic engagement and achievement (Saeid & Eslaminejad, 2016). ASE is a strong predictor of learning behaviour, SRL and performance, especially in the digital context. ASE is correlated with increasing technology adaptability, controlling learning effort, and SRL readiness. Furthermore, Self-regulation and effort are related to learners' confidence in their ability to sustain effort, control learning behaviour and persevere in the face of difficulties. Digital adaptation is confidence for effective learning through digital platforms, resources and technology-mediated activities. Collectively, these aspects describe the motivational ideas that allow professional teacher learners to cope with academic and technical challenges in a persistent, confident, adaptive way.

2.2. Digital Metacognition

The metacognition construct, gaining recognition in the field of educational psychology and related fields, relates to the awareness, modulation, and understanding of one's own thinking processes (Kuhn, 2000; Moshman, 2018; Schraw & Moshman, 1995). Metacognitive knowledge and awareness can be strengthened through reflective and self-regulatory practices such as self-questioning, self-assessment, and critical reflection (Ajani, 2024; Asiedu Menlah & Boateng, 2025). Metacognitive awareness encompasses both knowledge about cognition, including awareness of one's strategies, strengths, and limitations, and regulation of cognition through processes such as planning, monitoring, and evaluation; these capacities are also positively associated with learning performance (Asiedu Menlah & Boateng, 2025). Metacognitive skills therefore enable learners to recognize their cognitive strengths and limitations, establish appropriate goals, monitor their

progress, evaluate learning outcomes, and adjust their strategies when necessary (Ajani, 2024). In technology-mediated environments, these regulatory processes become particularly important because learners must actively interpret feedback, monitor their own understanding, and exercise judgment rather than rely uncritically on technological outputs (Okanya & Asogwa, 2026). Accordingly, digital metacognition can be conceptualized as distinct from, but complementary to, digital literacy: whereas digital literacy encompasses effective, critical, and informed engagement with digital technologies, digital metacognition concerns the conscious monitoring and regulation of cognition while learning with those technologies (Asiedu Menlah & Boateng, 2025; Okanya & Asogwa, 2026; Vasconcelos & Vasconcelos, 2022).

2.3. Self-Regulated Learning [SRL]

SRL emphasises student involvement in designing, monitoring, and assessing learning goals, tactics, and outcomes (Brunner et al., 2025; Schwam et al., 2021). SRL is rooted in cognitive and social-cognitive theories, particularly the model proposed by Zimmerman, who sees SRL as a cycle of planning, execution, and reflection (Zimmerman, 2000, 2002). Through SRL, learners do not rely solely on external instructions but consciously regulate their motivation, cognitive strategies, and learning behaviours to achieve predetermined academic goals.

SRL contributes significantly to improved academic achievement, learning engagement, and readiness for independent learning, particularly in digital and technology-based learning contexts (Zheng & Xiao, 2024). In general, high-level students of SRL are capable of setting clear learning goals, monitoring progress and changing learning tactics when obstacles arise (Saeid & Eslaminejad, 2016). Therefore, it is considered that SRL is a fundamental competence for the 21st century, fostering lifelong learning and being an essential foundation for the development of independence and learning readiness in a dynamic and digital educational environment. These dimensions capture the extent to which professional teacher learners are prepared to manage their learning independently and responsibly in digital environments.

2.4. The Relationship between Digital Metacognition, Academic Self-Efficacy, and Self-Regulated Learning Readiness

Studies on academic self-efficacy and self-regulated learning have slowly evolved from studying isolated connections to addressing more complicated cognitive–motivational interactions. Early technology-oriented research demonstrated that information and communication technology self-efficacy differed across learners' technology-use profiles, but conceptualised self-efficacy mainly as confidence to perform technological tasks rather than as a mechanism underlying learning regulation (Tømte & Hatlevik, 2011). Later studies linked ASE more with autonomous learning. Saeid and Eslaminejad (2016) found a substantial association between ASE and self-directed learning preparedness. Fokkens-Bruinsma et al. (2021) studied the role of ASE, together with autonomous motivation and time management, in explaining academic accomplishment. However, these studies were mainly correlational, or just regarded efficacy and regulatory factors as parallel predictors; the direction and mechanisms of their relationship were not well explained.

More recent research in digital and blended environments has provided evidence of potentially different causal directions. Sutherland et al. (2024) identified SRL as a significant predictor of ASE in blended learning, while Zheng and Xiao (2024) regarded online learning self-efficacy as an antecedent of online SRL, and showed that SRL mediated the link between online course satisfaction and online learning self-efficacy. Research on online teacher professional development has also indicated that digital learning experiences might enhance teachers' self-efficacy for supporting students' SRL, but this instructional efficacy is distinct from teachers' ASE as professional learners (Linde et al., 2023). However, these researchers were based on diverse populations and conceptualised self-efficacy as an antecedent, outcome or parallel predictor, which limits their potential to explain self-regulated learning preparedness among teachers as professional learners. Three gaps are still present. Digital metacognition, academic self-efficacy and self-regulated learning readiness have rarely been tested in one model. The simultaneous

mediating and moderating role of academic self-efficacy is underexamined. Evidence from teacher professional education is limited. The present study aims to fill these gaps by testing a questionnaire-based cognitive–motivational model in which academic self-efficacy plays a role as a direct predictor, statistical mediator, and moderator of the relation between digital metacognition and self-regulated learning readiness.

2.5. Hypothesis Development

Existing evidence broadly supports the relationships between metacognitive processes, academic self-efficacy, and self-regulated learning. However, previous studies have examined different kinds of metacognition and self-efficacy, have included populations from general university students to pre-service and in-service teachers, and have employed outcomes such as academic achievement, course satisfaction, strategy use or actual self-regulated learning behaviour instead of readiness, so the findings cannot be directly applied to the present model. Furthermore, most studies have studied either direct or mediating effects in isolation, therefore providing insufficient evidence for how academic self-efficacy might simultaneously explain and moderate the association between digital metacognition and self-regulated learning preparedness. Therefore, these contextual and methodological discrepancies need to be critically examined before formulating the hypotheses of the present investigation.

2.5.1. H1: Digital Metacognition and ASE

Digital metacognition is the learners' ability to plan, pay attention, assess, and manage their cognitive processes in technology-mediated learning contexts (Schraw & Moshman, 1995). According to the Social Cognitive Theory, people believe they can succeed in self-managing learning experiences, resulting in more robust efficacy beliefs (Bandura, 2015). People see themselves as competent in handling academic activities. Previous studies have shown that metacognitive competence positively influences learners' confidence, persistence, and perceived academic capability in digital learning contexts (Zheng & Xiao, 2024). Moreover, the largely correlational approach used in prior investigations leaves unresolved whether metacognitive competence augments effectiveness beliefs or whether students with greater efficacy beliefs tend to use metacognitive procedures more consistently. However, despite unresolved direction, the cognitive control involved in digital metacognition is theoretically predicted to give mastery-related knowledge that enhances learners' academic confidence.

Therefore, H1. Digital metacognition is positively associated with academic self-efficacy.

2.5.2. H2: Digital Metacognition and SRL Readiness

According to the SRL theory, this requires planning, monitoring, and assessing learning activities (Zimmerman, 2000). In digital environments, metacognitive skills enable learners to organise learning resources, monitor progress, and adapt strategies according to learning needs. Empirical evidence suggests that learners with higher metacognitive awareness tend to demonstrate stronger readiness for autonomous and self-directed learning (Kic-Drgas & Kılıçkaya, 2024). Therefore, the present results point to a general association between metacognitive regulation and self-directed learning, but do not directly indicate whether digital metacognition is connected with self-regulated learning preparedness in in-service teachers. Digital metacognition is anticipated to be a crucial cognitive foundation for such readiness, as readiness requires learners to view themselves as capable of planning, monitoring, and changing their learning before and throughout technology-mediated activities.

Therefore: H2. Digital metacognition is positively associated with self-regulated learning readiness.

2.5.3. H3: Academic Self-Efficacy and SRL Readiness

Bandura (2015) suggested that self-efficacy affects people's choices, the amount of effort they expend, and the length of time they continue to try when they confront obstacles. Students with

high ASE are more likely to establish demanding goals for themselves, retain their motivation and govern their learning (Zimmerman, 2000). Recent research has repeatedly indicated that SE is a powerful predictor of SRL behaviours and readiness in virtual and hybrid learning environments (Sutherland et al., 2024). In addition, the prior studies tended to focus on the actual self-regulated learning behaviour or academic accomplishment rather than learners' readiness to manage learning. The present cross-sectional study cannot demonstrate temporal direction, but explores the theoretically hypothesised association in which academic self-efficacy acts as a motivational resource that supports perceived preparation for SR.

Therefore: H3. Academic self-efficacy is positively associated with self-regulated learning readiness

2.5.4. H4: The Mediating Role of ASE

It is possible that digital metacognition and self-regulated learning preparedness are not directly related, but their association is mediated by psychological mechanisms that increase learners' confidence. Metacognitive competence enables learners to regulate their learning processes, therefore enhancing academic self-efficacy (Linde et al., 2023). This, in turn, increases self-efficacy, which leads learners to use self-regulatory strategies more consistently and effectively (Usher & Pajares, 2008). This notion is backed by earlier studies indicating that SE often influences the association between cognitive abilities and learning outcomes (Yuan et al., 2024). However, most of this research has focused on academic accomplishment, deep learning, procrastination or strategy use but not on self-regulated learning preparedness. Nor have they directly examined digital metacognition, academic self-efficacy and preparation in one type of teacher professional education. The hypothesised mediation is therefore theoretically viable but empirically underexplored in the present setting.

Therefore: H4. Academic self-efficacy statistically mediates the association between digital metacognition and self-regulated learning readiness.

2.5.5. H5: Moderating Effect of ASE

Social Cognitive Theory posits that cognitive abilities can have varied results based on individuals' efficacy beliefs (Bandura, 2015). Students with advanced metacognitive abilities may not be able to use these talents effectively without confidence in their academic ability. On the other hand, persons with strong ASE are more likely to convert their metacognitive awareness into effective SRL behaviours (Tsai et al., 2024).

The contribution of the study expands the literature in three ways. First, it integrates cognitive, metacognitive, and motivational perspectives within a single explanatory cognitive–motivational model. Second, it extends Social Cognitive Theory by positioning academic self-efficacy as both a mediating and moderating mechanism (Bandura, 2001, 2015). Third, it provides empirical evidence from the context of professional teacher education, which remains underrepresented in studies of digital SRL. Accordingly, the moderation hypothesis represents an extension of Social Cognitive Theory that requires direct empirical testing rather than a replication of an already established relationship.

Therefore: H5. Academic self-efficacy statistically moderates the association between digital metacognition and self-regulated learning readiness, such that the positive association is stronger at higher levels of academic self-efficacy.

2.6. Aim of the Study and Research Questions

This study aims to empirically test a cognitive–motivational model explaining the relationships among digital metacognition, academic self-efficacy, and self-regulated learning readiness among participants in teacher professional education. Using self-report questionnaire data, the study examines the direct relationships among these three constructs and investigates whether academic self-efficacy functions as both a mediator and a moderator in the relationship between digital

metacognition and self-regulated learning readiness. Accordingly, the study addresses the following research questions:

RQ 1) To what extent is digital metacognition associated with academic self-efficacy among participants in teacher professional education?

RQ 2) To what extent is digital metacognition associated with self-regulated learning readiness among participants in teacher professional education?

RQ 3) To what extent is academic self-efficacy associated with self-regulated learning readiness among participants in teacher professional education?

RQ 4) Does academic self-efficacy statistically mediate the relationship between digital metacognition and self-regulated learning readiness?

RQ 5) Does academic self-efficacy statistically moderate the relationship between digital metacognition and self-regulated learning readiness, such that this relationship is stronger at higher levels of academic self-efficacy?

3. Method

3.1. Research Design

This study employed a quantitative, non-experimental, cross-sectional design to assess a cognitive–motivational model of self-regulated learning readiness among 462 in-service teachers enrolled in the Indonesian Teacher Professional Education programme. Data were obtained via a self-report questionnaire and processed by covariance-based structural equation modelling in LISREL version 8.70 (Brown, 2015; Kline, 2023). Confirmatory factor analysis was performed to assess the measurement models, then structural model analysis was conducted to investigate the direct, indirect, and interaction effects of digital metacognition, academic self-efficacy, and self-regulated learning preparedness. Since the variables were measured at one point in time without experimental manipulation, the results were interpreted as statistical associations rather than causal links.

3.2. Population and Sample

The population is 901 practising teachers who are active and registered in the Teacher Professional Education program at the Universitas Islam Makassar. Researchers did not randomly choose teachers but invited all qualified teachers using a total-population recruitment strategy. The final sample includes 462 practising teachers in early childhood education, elementary, junior high, and senior high/vocational schools. Participants were eligible when they were teachers in a job, formally registered in the programme, had expertise with digitally mediated learning, and willingly decided to participate.

3.3. Respondents Characteristics

Participants were also asked to indicate their level of experience in using technology for learning by selecting one of three self-rated categories: low, moderate, or high. The rating reflected participants' perceived familiarity and experience with digital learning technologies rather than their objectively measured technological competence.

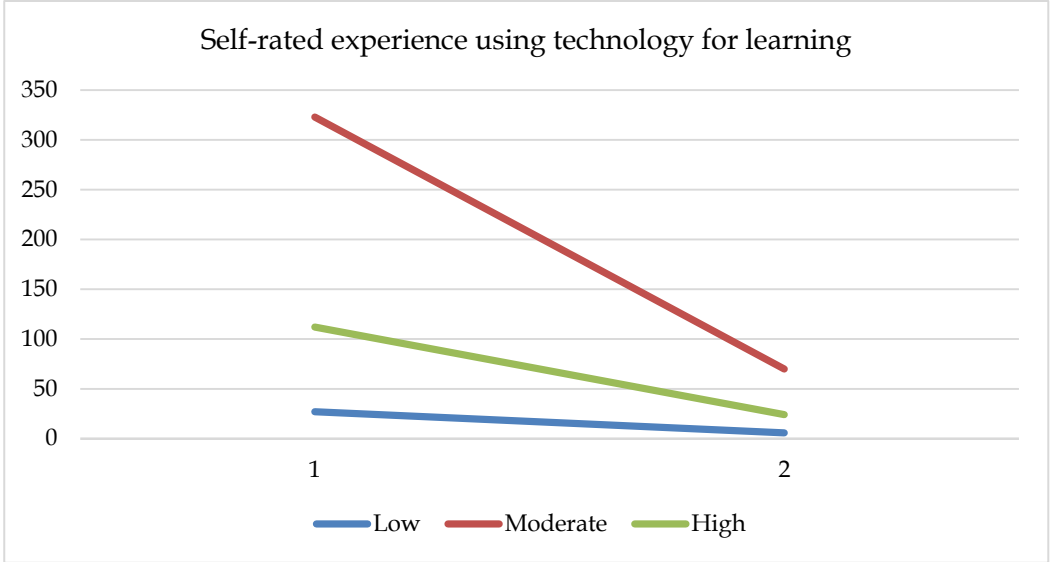
Table 1 shows that the participants varied in their demographics and professional backgrounds. Most were teachers 26 years and older who taught at the primary or secondary school level. Most had five to six years of teaching experience, had a bachelor's degree in education, and indicated modest expertise with technology for learning. Most participants also routinely used digital learning systems. These features suggest that the sample had relevant teaching experience, pedagogical preparation, and exposure to technology-mediated learning. These traits were employed to contextualise the sample, and not as explanatory factors in the structural model. Furthermore, the structural model did not include them as predictors or control variables because the suggested model was primarily designed to test the cognitive and motivational links between digital metacognition, academic self-efficacy and self-regulated learning readiness.

Table 1
Profiles of Participants' Demographic and Professional Characteristics

Profile	*n*	*%*
Gender		
Male	260	56.3
Female	202	43.7
Age		
23 years or younger	31	6.7
24–25 years	49	10.6
26 years or older	382	82.7
School level		
Early Childhood Education	51	11.0
Elementary School	166	35.9
Junior High School	129	27.9
Senior High School/Vocational School	116	25.1
Participant status		
Practising teachers	462	100.0
Teaching experience		
3–4 years	138	29.9
5–6 years	317	68.6
7 years or more	7	1.5
Undergraduate academic background		
Non-education-related field	47	10.2
Education-related field	415	89.8
Frequency of use of digital learning platforms		
Every day	176	38.1
1–2 times per week	90	19.5
3–4 times per week	137	29.7
Rarely	59	12.8
	462	100%

Participants were asked to choose one of three categories—low, moderate, or high—to describe their experience utilising technology for learning. These categories did not provide an objective evaluation of the participants' technological proficiency; rather, they represented their self-perceived knowledge and expertise with digital learning technology.

Figure 1
Self-Rated Experience Using Technology for Learning



The majority of participants (69.9%) stated they had moderate experience utilising technology for learning, while those with high-level experience (24.2%) came in second. The sample appears to have had adequate exposure to technology-mediated learning, since only a small percentage (5.8%) gave their experience a low rating.

3.4. Instruments

A systematic questionnaire was used to collect data on digital metacognition, ASE, and readiness for SRL. The instrument was adapted from existing theoretical cognitive–motivational models such as digital metacognition (Schraw et al., 2006), academic self-efficacy (Bandura, 2006; Usher & Pajares, 2008) and self-regulated learning (Zimmerman & Martinez-Pons, 1988) and contextualised for the PPG programme. The characteristics were selected because of their theoretical importance for cognitive regulation, academic confidence and independent learning in digital environments. Three educational technology, educational psychology, and teacher education experts checked the instrument's content validity and contextual relevance before data collection. Confirmatory Factor Analysis [CFA] measured construct validity, whereas Composite Reliability [CR] and Average Variance Extracted measured reliability and convergent validity. All concepts met validity and reliability requirements (Brown, 2015).

To ensure a consistent interpretation of the questionnaire items, digital learning platforms were defined as learning management systems, video-conferencing applications, electronic module platforms, online assessment systems, institutional learning portals and other digital applications used by participants during the Teacher Professional Education programme, in the questionnaire instructions. Hence, the term referred to platforms that provided access to materials, synchronous and asynchronous learning, submission of assignments, assessment, feedback, and academic interaction.

Table 2 shows the descriptive statistics for digital metacognition. All of the participants reported rather high levels of perceived digital metacognition (M = 4.13, SD = 0.69), and the concept showed strong internal consistency (Cronbach's α = .979). Among representative questions, the highest mean score was arranging devices and internet connection before digital learning (M = 4.32, SD = 0.66), followed by choosing digital resources and applications according to learning needs (M = 4.25, SD = 0.65). The lowest mean was registered for perceived ability to independently manage the digital learning process (M = 4.03, SD = 0.75); however, this value was still quite high. Generally, the results indicate that the in-service teachers felt capable of planning, preparing, and managing learning activities in digital environments.

Table 2
Descriptive Statistics Digital Metacognition

No.	Latent Construct	Mean	SD	Reliability*
	Digital Metacognition	4.13	0.69	.979
1	Determine learning goals before using digital platforms.	4.08	0.73	.762
2	Select digital resources and applications according to my learning needs.	4.25	0.65	.783
3	Prepare devices and an internet connection before digital learning.	4.32	0.66	.792
4	Estimate the time required to complete digital tasks.	4.10	0.76	.801
5	Feel capable of managing the digital learning process independently.	4.03	0.75	.822

Note. Only representative items are presented. The complete instrument is provided in the Appendix as supplementary material.

Table 3 represents the Self-Regulated Learning and Readiness Instrument were used to measure respondents' level of readiness to manage their learning autonomously (Zimmerman, 2002). Aspects measured include setting learning goals, time management, utilising digital learning resources, controlling motivation, and reflecting on the learning process and outcomes (Zimmerman, 2000). This construct is positioned as the dependent variable representing the psychological and strategic readiness of PPG teachers to face the demands of digital learning.

Table 3
Descriptive statistics of self-regulated learning readiness

No.	*Latent Construct*	*Mean*	*SD*	*Reliability**
	Self-Regulated Learning Readiness	4.15	0.65	.983
1	Able to organise a regular study schedule.	4.10	0.70	.867
2	Study even without instruction or supervision from lecturers.	4.09	0.66	.875
3	Able to prioritize academic assignments over other activities.	4.15	0.61	.880
4	Able to complete assignments according to a predetermined plan.	4.15	0.62	.885
5	Comfortable learning through various digital media such as videos, e-modules, and interactive simulations.	4.20	0.65	.815

Note. Only representative items are presented. Reliability is measured by Cronbach's alpha for the construct and factor loadings for the observed variables.

Table 4
Descriptive statistics of academic self-efficacy

No.	*Latent Construct*	*Mean*	*SD*	*Reliability**
	Academic Self-Efficacy	4.10	0.69	.981
1	Confident in understanding the course material, even when it is difficult.	4.05	0.71	.830
2	Confident in following the learning process effectively, whether face-to-face or online.	4.16	0.62	.824
3	Confident in explaining the material learned.	4.03	0.67	.863
4	Confident in being able to learn independently.	4.07	0.70	.841
5	Confident in being competent in learning in a digital technology-based environment.	4.08	0.69	.909

Note. Only representative items are presented. The complete instrument is provided in the Appendix as supplementary material. Reliability is measured by Cronbach's alpha for the construct and factor loadings for the observed variables

Table 4 indicates that the Academic Self-Efficacy Instrument measures respondents' confidence in their ability to complete academic tasks, overcome learning difficulties, and achieve set learning targets (Bandura, 2015). ASE is designated as a moderating variable believed to enhance or weaken the influence of digital metacognition on readiness for independent learning.

The research instrument consisted of a structured questionnaire that included three constructs: digital metacognition, ASE, and SRL readiness. The instrument was created with Zimmerman (2000) of self-regulated learning theory, Bandura (2015) of SE theory, then tailored to the realm of digital learning and teacher professional development. All items were evaluated using a five-point Likert scale, with 1 representing 'strongly disagree' and 5 indicating 'strongly agree.' Before administration, the instrument underwent content validation by three experts in educational technology, educational psychology, and teacher education to assess the relevance, intelligibility, and appropriateness of the constructs. Additionally, construct validity was assessed by CFA, while reliability was evaluated using CR and AVE metrics. The test findings demonstrated that all constructs met the established validity and reliability standards; therefore, they are suitable for application in this study.

3.5. Data Collection

Data were collected through an online self-report questionnaire (Google Forms) from October 2025 to January 2026. The URL of the questionnaire was disseminated through the official WhatsApp groups of teachers joining the Teacher Professional Education programme at Universitas Islam Makassar. All 901 qualified teachers were invited to participate voluntarily. Of them, 462 completed and returned the questionnaire, and 439 did not answer, giving a response percentage of 51.3%. All the questionnaires provided were verified for eligibility, completeness, and duplicates, and all 462 valid replies were retained for analysis

3.6. Data Analysis

Data analysis applied covariance-based structural equation modelling [CB-SEM] using Lisrel 8.70 to concurrently evaluate the conceptual model and the structural relationships among latent variables (Brown, 2015; Kline, 2023). The measurement models were examined by means of factor loadings, composite reliability, average variance extracted, and model-fit indices. Finally, the structural model was tested for three direct links, the indirect influence of digital metacognition on self-regulated learning readiness through academic self-efficacy, and the interaction effect between digital metacognition and academic self-efficacy. Standardised coefficients, t-values and p-values were used to evaluate the statistical significance of the structural routes, while the R2 was used to estimate the proportion of variation explained in the endogenous constructs.

The mediation and moderation roles of academic self-efficacy were examined as separate processes in the same structural model. We performed a product-of-coefficients technique to assess the mediation, estimating the indirect impacts of digital metacognition on self-regulated learning readiness through academic self-efficacy. We established the interaction term of digital metacognition and academic self-efficacy and included it as a predictor of self-regulated learning readiness for the moderation analysis. The interaction term coefficients are statistically significant, indicating that the association between digital metacognition and self-regulated learning readiness is moderated by academic self-efficacy. The positive interaction coefficient suggested that the association between digital metacognition and self-regulated learning readiness was stronger when academic self-efficacy was higher. The mediation and moderation analysis was performed as a separate analysis and not as a moderated mediation model.

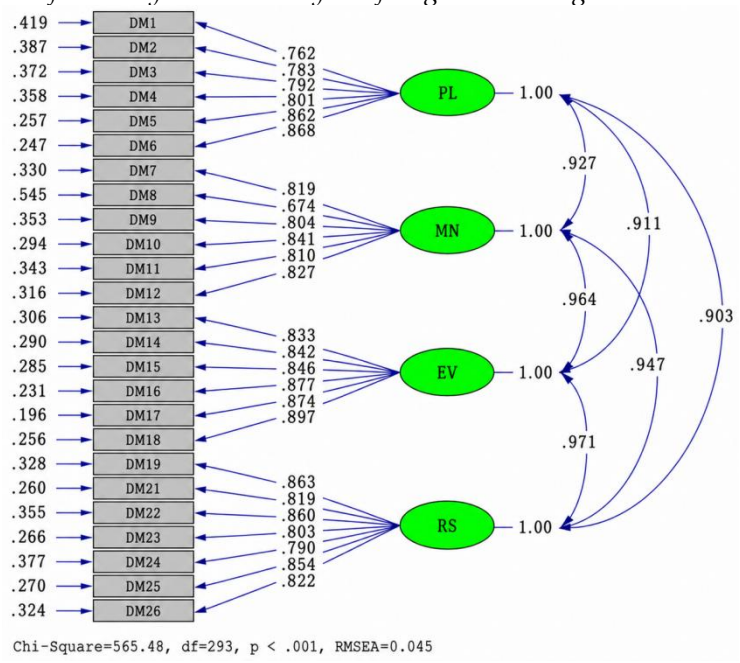
4. Findings

The results are presented in two phases. First, confirmatory factor analysis was used to assess the measurement models to check the factor loadings, construct reliability, convergent validity, and goodness-of-fit of digital metacognition, academic self-efficacy, and self-regulated learning readiness. Second, the structural model was estimated to analyse hypothesised direct correlations among the three dimensions and to explore the statistical mediating and moderating effects of academic self-efficacy.

The results of the evaluation of the measurement model are presented, and then the results of the evaluation of the structural model are presented.

Figure 2

Confirmatory Factor Analysis of Digital Metacognition



Based on the loading factor (λ) in Figure 2, the results of the measurement model test for each dimension of the digital metacognition latent variable are presented in the following Table 5.

Table 5
Summary of Confirmatory Factor Analysis Results for Digital Metacognition

Dimension	*Dominant Indicator*	*Highest Loading*	*CR*	*AVE*
Planning (PL)	DM6	.868	.921	.660
Monitoring (MN)	DM10	.841	.913	.636
Evaluation (EV)	DM18	.897	.945	.743
Regulative Strategy (RS)	DM19	.863	.948	.695

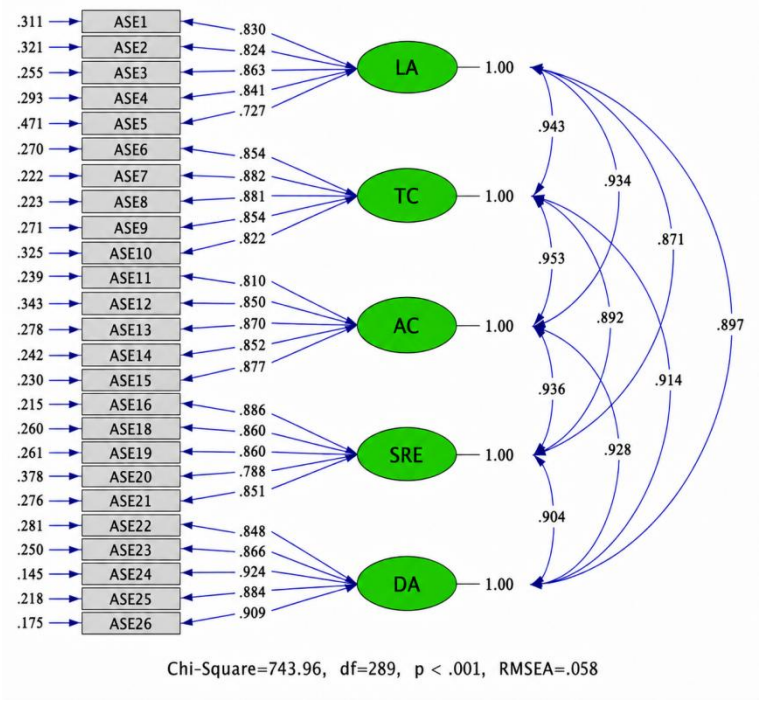
Note. Model Fit: RMR = .013; RMSEA = .045; GFI = .829; NFI = .991; NNFI = .995; CFI = .996; RFI = .990; IFI = .996.

Table 5 presents the summary of the outcome of the confirmatory factor analysis of digital metacognition. All dimensions presented good validity and reliability. The values of construct reliability were above the suggested threshold, and the AVE values showed an adequate convergent validity. Of the four components, evaluation was the strongest component of digital metacognition, followed by regulative strategy, planning and monitoring. The model also provided an adequate fit to the data, indicating the adequacy of the measurement model.

4.1. Confirmatory Factor Analysis: ASE

ASE comprises five categories and is measured through 26 indicators. A measurement model for each variable of ASE was derived by confirmatory factor analysis, as seen in Figure 3.

Figure 3
Confirmatory Factor Analysis Diagram for ASE



Based on the factor loadings (λ) in Figure 3, the results of the measurement model testing for each dimension of the latent variable of academic self-efficacy are presented in the following Table 6.

Table 6 demonstrates that all first order five-dimensions of academic self-efficacy had sufficient validity and reliability. Digital adaptation had the highest loading (.924), reflecting that confidence in adapting to technology-mediated learning was well represented at the first-order level. However, Table 8 revealed that the second-order model indicated academic challenge as the greatest dimension of the total academic self-efficacy construct. These findings apply to distinct levels of measurement and hence are complementary rather than contradicting.

Table 6
Summary of Confirmatory Factor Analysis Results for Academic Self-Efficacy

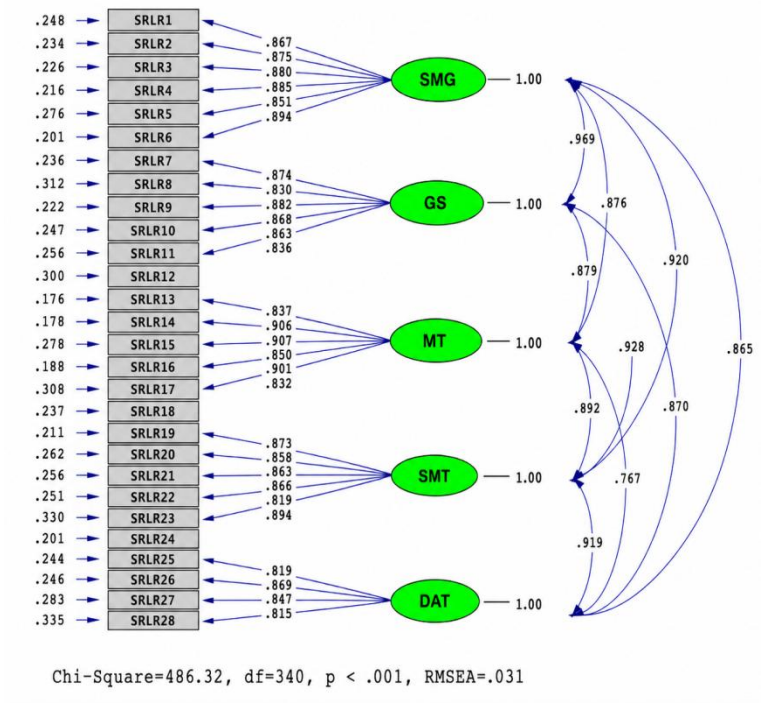
Dimension	*Dominant Indicator*	*Highest Loading*	*CR*	*AVE*
Learning Ability (LA)	ASE3	.863	.910	.670
Task Completion (TC)	ASE7	.882	.934	.738
Academic Challenge (AC)	ASE11	.873	.929	.725
Self-Regulation & Effort (SRE)	ASE17	.886	.931	.731
Digital Adaptation (DA)	ASE24	.924	.954	.776

Note. Model Fit: RMR = .020; RMSEA = .058; GFI = .749; NFI = .989; NNFI = .993; CFI = .993; RFI = .988; IFI = .993.

4.2. Confirmatory Factor Analysis in SRL Readiness

Self-regulated learning readiness encompasses five characteristics and is measured through 28 indicators. A measurement model for each dimension of self-regulated learning readiness was derived by confirmatory factor analysis, as seen in Figure 4.

Figure 4
Diagram of Confirmatory Factor Analysis in SRL Readiness



Based on the loading factor (λ) in Figure 4, the results of the measurement model test for each dimension in the latent variable SRL readiness are presented in the following Table 7.

Table 7
Summary of Confirmatory Factor Analysis Results for SRL Readiness

Dimension	*Dominant Indicator*	*Highest Loading*	*CR*	*AVE*
Self-Management (SMG)	SRLR6	.894	.952	.766
Goal Setting (GS)	SRLR9	.882	.936	.746
Motivation (MT)	SRLR13	.908	.951	.762
Self-Monitoring (SMT)	SRLR19	.888	.940	.757
Digital Autonomy (DAT)	SRLR24	.894	.941	.727

Note. Model Fit: RMR = .014; RMSEA = .031; GFI = .817; NFI = .994; NNFI = .998; CFI = .998; RFI = .993; IFI = .998.

The results of the confirmatory factor analysis for SRL readiness are presented in Table 7. All dimensions had good construct validity and reliability. All loading factors were acceptable, construct reliability values were high, and AVE values were above the required cutoff. The dimensions of self-management had the highest convergent validity, and goal setting was the most

dominant reflector at the latent construct level. The data suggest that the preparation of PPG teachers in autonomous learning in digital environments includes effective goal formulation, self-management, motivation, self-monitoring, and digital autonomy. The measuring model also showed an adequate fit, which confirmed the appropriateness of the construct of SRL preparedness.

4.3. Latent Variable Measurement Model Evaluation

The latent variable scores derived from the confirmatory factor analysis were subsequently utilised as input data for the evaluation of the latent variable measurement model. The evaluation results of the measurement model for each latent variable, derived from the analysis of the latent variable scores, were as in Table 8.

Table 8
Measurement Model Evaluation Results for Each Latent Variable

Latent Variable	*Dominant Dimension*	*Loading*	*CR*	*AVE*
Digital Metacognition	Evaluation	.989	.983	.937
Academic Self-Efficacy	Academic Challenge	.982	.983	.921
Self-Regulated Learning Readiness	Goal Setting	.987	.973	.878

Table 8 presents the evaluation results of the latent constructs. All constructs demonstrated excellent convergent validity and internal consistency, as indicated by loading factors, composite reliability values, and AVE values exceeding the recommended thresholds. Digital metacognition was most strongly reflected by the evaluation dimension, ASE by academic challenge, and SRL readiness by goal setting. These findings confirm that the proposed constructs possess strong explanatory power and are theoretically and empirically appropriate for representing cognitive, motivational, and self-regulatory processes in digital learning environments. At the second-order level, academic challenge showed the highest loading on academic self-efficacy (.982), followed closely by the other dimensions. This indicates that confidence in dealing with difficult academic tasks was the most prominent dimension of the overall academic self-efficacy construct in the present sample.

The path diagram illustrating the impact of digital metacognition on SRL readiness, with ASE as a moderating variable, is presented in the following Figure 5.

Figure 5
Estimated Structural Model of the Cognitive–Motivational Relationships

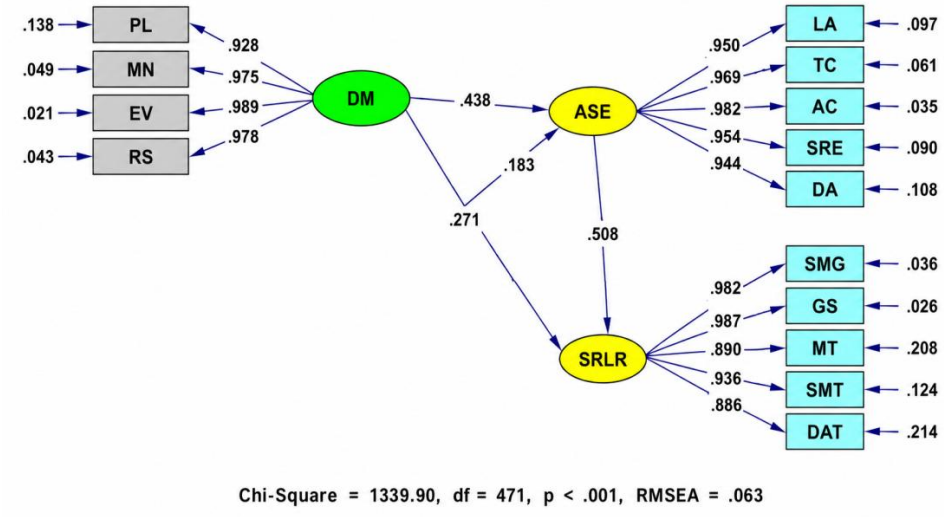


Figure 5 shows the estimated structural correlations among digital metacognition, academic self-efficacy, and self-regulated learning preparedness based on the replies of the participants to the questionnaire. The model includes the direct paths between the three constructs, the indirect

path through academic self-efficacy, and the interaction between digital metacognition and academic self-efficacy.

4.4. Goodness of Fit Test

The goodness-of-fit test is performed to assess whether the estimated findings accurately represent the relationships among the variables under study, thereby classifying the model as effective.

Table 9
Goodness-of-Fit Indices for the Proposed Model

Fit index	*Recommended criterion*	*Obtained value*	*Evaluation*
Chi-square (*p*-value)	Preferably non-significant	$p < .001$	Significant; sensitive to sample size
χ^2/df	< 3.00	2.84	Acceptable
GFI	≥ .90	.652	Below criterion
RMSEA	< .08	.063	Acceptable
RMR	< .08	.046	Acceptable
NFI	≥ .90	.987	Good
NNFI/TLI	≥ .90	.990	Good
RFI	≥ .90	.984	Good
IFI	≥ .90	.991	Good
CFI	≥ .90	.991	Good

Table 9 shows that the structural model showed mixed but acceptable fit overall. The χ^2/df, RMSEA, RMR, NFI, NNFI/TLI, RFI, IFI, and CFI values met commonly accepted cut-off criteria, although the GFI was .652 and less than the recommended threshold. The low GFI may be due to the intricacy of the model and the sensitivity of this indicator to sample and parameter factors. The model was thus considered generally acceptable rather than excellent.

4.5. Evaluation of the Cognitive–Motivational Model

After the evaluation of the measurement models, the suggested cognitive–motivational model of self-regulated learning readiness was empirically tested using structural equation modelling. The direct relationships of digital metacognition, academic self-efficacy and self-regulated learning preparation, as well as the statistical mediating and moderating effects of academic self-efficacy, were the focus of the analysis.

The mediating and moderating functions of academic self-efficacy were explored as different mechanisms within the same model. The indirect effect was the mediating mechanism, and the interaction term was the moderating mechanism. No conditional indirect effects were assessed.

Table 10
Structural Model Results

Hypothesis	*Path*	*Effect Type*	*β*	*t-value*	*p-value*	*Decision*
H1	DM → ASE	Direct	.438	7.622	< .001	Supported
H2	DM → SRLR	Direct	.271	2.428	.015	Supported
H3	ASE → SRLR	Direct	.508	5.295	< .001	Supported
H4	DM → ASE → SRLR	Indirect (Mediation)	.223	4.777	< .001	Supported
H5	DM × ASE → SRLR	Moderation	.183	2.335	.020	Supported

Table 10 shows the structural analysis offered empirical support for the suggested cognitive–motivational model of self-regulated learning readiness in the current sample. Digital metacognition was positively associated with academic self-efficacy (β = .438, t = 7.622, $p < .001$) and self-regulated learning readiness (β = .271, t = 2.428, p = .015), and academic self-efficacy showed the strongest direct association with readiness (β = .508, t = 5.295, $p < .001$). Academic self-efficacy also statistically mediated the connection between digital metacognition and preparedness (β = .223, t = 4.777, $p < .001$) and significantly moderated this association (β = .183, t = 2.335, p =

.020). Thus, academic self-efficacy served as a direct predictor, mediator, and moderator in the tested model.

The model explained 19.2% of variance in academic self-efficacy and 54.2% of variance in self-regulated learning readiness. These findings provide support for a cognitive–motivational interpretation where digital metacognition reflects in-service teachers perceived capacity to plan, monitor, evaluate, and regulate digital learning, while academic self-efficacy reflects the motivational confidence linked to applying these capacities in autonomous learning. However, since all constructs were assessed at the same time point via self-report questionnaires, the model should be interpreted as an empirically supported representation of statistical associations within the present sample, and not as evidence for temporal or causal relationships.

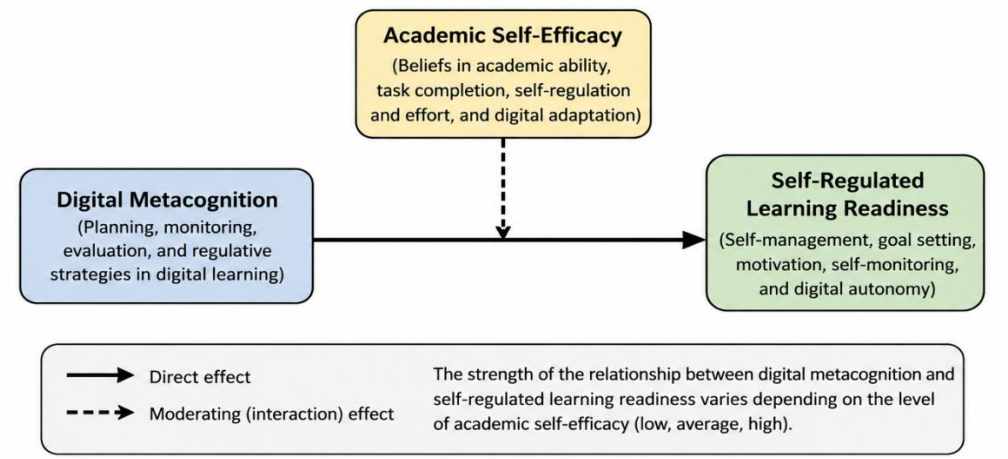
As shown in Table 11, the model showed moderate explanatory power for self-regulated learning readiness (R^2 = .542), while the explanatory power for academic self-efficacy was relatively low (R^2 = .192), suggesting that other factors beyond digital metacognition may contribute to the development of academic self-efficacy among PPG teachers.

Table 11
Explained Variance (R^2)

Endogenous Variable	R^2
Academic Self-Efficacy (ASE)	.192
Self-Regulated Learning Readiness (SRLR)	.542

Figure 6 shows the conceptual moderating effect of academic self-efficacy on the relationship between digital metacognition and self-regulated learning readiness. The model indicates that the strength of this association may differ based on in-service teachers' levels of academic self-efficacy. Therefore, the relationship between digital metacognitive competence and self-regulated learning readiness would be more strongly positive in the context of higher academic self-efficacy.

Figure 6
Conceptual Diagram of the Moderating Role of ASE in the Relationship between DM and SRL Readiness



Note. Digital metacognition refers to learners' metacognitive processes when using digital learning platforms. Academic self-efficacy represents learners' beliefs in their academic capabilities in digitally mediated learning. Self-regulated learning readiness reflects learners' preparedness to manage their learning independently in digital learning environments.

5. Discussion

This study empirically tested a cognitive–motivational model of self-regulated learning readiness to participate in professional education among in-service teachers. In this model, the cognitive component was digital metacognition, the motivational component was academic self-efficacy, and the participants' perceived readiness for autonomous learning was self-regulated learning readiness. The results validated the hypothesised direct correlations and the statistical mediating and moderating roles of academic self-efficacy. This underscores the importance of integrating

cognitive and motivational factors. The dual function of SE suggests that there is a conditional process involved rather than just a direct relationship.

The most dominant components were the evaluation and regulation strategy dimensions of the digital metacognition variable. These findings validate that the ability to evaluate the efficiency of digital learning strategies and technology, and the ability to dynamically modify learning approaches, are at the basis of digital metacognition. PPG teachers programme capable of critically reflecting on their learning processes are more adaptive to the changes in the digital learning context and better equipped to make appropriate learning decisions. This is consistent with the concept that digital metacognition involves not only awareness of cognition but also strategic decision-making skills in technology-based learning contexts (Adams et al., 2025).

The planning and monitoring dimensions are also included in the construction of digital metacognition, but in a facilitative manner. The ability to set digital learning objectives and assess learning progress allows the PPG programme to manage time, learning resources and tactics more efficiently. However, without evaluative and regulatory abilities, the procedures of planning and monitoring are often mechanical and have little impact on the improvement of learning quality. Thus, the integration of these four metacognitive elements is essential for the development of a full digital metacognition.

In the dimension of academic self-efficacy, research results show that academic confidence of PPG teachers is affected by the combination of cognitive ability, the spirit of finishing tasks, the courage to face academic problems, and the ability to regulate learning efforts and adapt to digital learning. The academic challenge dimension is the strongest reflector, indicating that self-efficacy is most evident when individuals remain confident in their abilities despite facing difficulties (Yuan et al., 2024). In the context of digital learning, which demands a high degree of independence, this belief becomes a crucial psychological factor (Zheng & Xiao, 2024). The existence of the digital adaptation dimension within academic self-efficacy also confirms that academic confidence in the digital age is no longer limited to traditional cognitive abilities, but encompasses the ability to overcome technological barriers and utilise learning platforms effectively (Çetin, 2022). PPG teachers with high SE tend to view digital challenges as learning opportunities, rather than obstacles, thus being better able to maintain motivation and consistency in learning. This shows that psychology motivates students to attain academic goals (Bandura, 2015).

In the meantime, self-regulated learning readiness was a construct that indicated a comprehensive readiness for independent learning. The goal-setting dimension is the most crucial factor, given that preparation for autonomous learning is strongly dependent on clarity of learning goals and direction. Braad et al. (2022) revealed that students' understanding of certain parts of their functioning could improve self-regulation. However, Self-awareness, not always possible without basic competencies, can contribute to the readiness necessary for personal change (Zimmerman, 2002). PPG teachers who set clear and relevant learning goals are likely to be more organised, motivated and able to evaluate the success of their learning independently. The full preparation for autonomous learning is composed of the elements of self-management, motivation, self-monitoring and digital autonomy in addition to goal-setting. The data suggest that SRL preparation is an issue not just of learning skills but also of mental readiness and attitudes to autonomous learning. This form of readiness is particularly relevant in teacher professional education, where teachers are expected to remain active participants in their own professional learning. Effective professional development requires teacher agency, reflective decision-making, and meaningful engagement rather than passive participation (Badal, 2025), while continuous professional development provides an important mechanism through which teachers update and apply professional knowledge and competencies over time (Parry & Kumi, 2026).

The relationship between digital metacognition and ASE indicates that the ability to reflectively manage digital learning processes was positively associated with academic self-efficacy. When PPG teachers can understand, evaluate, and control their digital learning strategies, they tend to

feel more competent and confident in facing academic demands. These findings contribute to the knowledge of SE formation by identifying digital metacognition as an important source of academic confidence (Linde et al., 2023). The importance of digital metacognition is directly related to preparation for SRL. Metacognitive skills also help PPG teachers become more intentional and autonomous in their learning management, therefore making them more prepared to engage in learning that requires a high level of independence. However, this effect is higher when there are sufficient levels of ASE, demonstrating that cognitive techniques should be backed by psychological beliefs for optimal execution (Sutherland et al., 2024). The metacognitive teaching technique improves students' programming skills, academic motivation, and SE in resisting technology use (Tsai et al., 2024). The imperative of cultivating digital literacy, social support networks, and metacognitive skills to enhance student SE.

The mediating role of ASE suggests that the effect of digital metacognition on SRL readiness is mediated primarily by the enhanced confidence of ASE. Digital metacognition offers a cognitive–motivational model for learning strategies and awareness (Kic-Drgas & Kılıçkaya, 2024). Self-efficacy defines the degree to which learning strategies are implemented consistently and sustainably (Alenezy et al., 2022). When there is no confidence in one's talents, the metacognitive potential is often left untapped. Moreover, ASE also acts as a moderator to enhance the association between digital metacognition and SRL preparedness. It indicates that academic beliefs operate as a moderating factor that influences the magnitude of the impact of digital metacognition on SRL readiness. In other words, PPG teachers with high SE derive greater benefits from their digital metacognitive abilities.

Theoretically, this study contributes to SRL Theory and Social Cognitive Theory by demonstrating that SRL readiness arises from the interaction of cognitive and motivational processes within digital learning environments. Digital metacognition is a basic cognitive mechanism enabling learners to organise, monitor, assess and manage their learning activities, according to Self-Regulated Learning Theory (Zimmerman, 2002). However, the present findings extend this view by showing that metacognitive competencies alone are not adequate to fully explain preparation for autonomous learning. Based on Social Cognitive Theory (Bandura, 1997), ASE is identified as a crucial motivational source that helps translate metacognitive awareness into learning preparedness and also enhances the efficacy of metacognitive processes. The present study provides a more comprehensive cognitive-motivational account of self-regulated learning readiness and contributes to the current theoretical understanding of independent learning in digitally mediated professional educational contexts by conceptualising academic self-efficacy as both a mediating and moderating variable.

The findings of this study contribute theoretically to the digital learning literature by providing a cognitive–motivational model that integrates cognitive, metacognitive and psychological factors. Findings reinforce that effective digital learning depends not only on technological and pedagogical factors but also on learners' academic self-efficacy and their readiness to engage in self-regulated learning (Bandura, 2001; Domino & Shaffer, 2025). In practical terms, the results of this study have substantial implications for the implementation among in-service teachers enrolled in the Indonesian Teacher Professional Education programme. Improving digital metacognition should be paired with systematic interventions to enhance ASE through structured reflection, constructive feedback and challenging but manageable learning opportunities. Hence, the PPG teachers may grow as independent learners who are ready to handle the dynamism of education in the digital world.

The originality of this study is represented by the integration of digital metacognition, academic self-efficacy and self-regulated learning readiness in a consistent cognitive–motivational model. Unlike previous research that focused mostly on direct relationships, the present study conceptualised academic self-efficacy as a statistical mediator and moderator of the relationship between digital metacognition and self-regulated learning preparedness. The moderating mechanism clarifies whether the positive association between digital metacognition and self-

regulated learning readiness grows stronger with higher levels of academic self-efficacy. By highlighting SRL readiness in digital learning and the role of teachers' academic beliefs, this study expands the body of SRL theory (Osman & Hannafin, 1992) while providing practical contributions to the design of professional learning policies and interventions based on strengthening ASE and metacognition.

6. Conclusion

This study empirically examines a cognitive–motivational model of self-regulated learning readiness among 462 teachers enrolled in the Indonesian Teacher Professional Education program. Perceived digital metacognition is positively related to both academic self-efficacy and self-regulated learning readiness, and academic self-efficacy had the largest direct association with readiness. Academic self-efficacy statistically mediated and moderated the connection between digital metacognition and self-regulated learning readiness. The model accounts for 19.2% of the variance in academic self-efficacy and 54.2% of the variance in self-regulated learning readiness, indicating that perceived cognitive regulation and motivational confidence together significantly account for PPG teachers' readiness for self-regulated learning in digital environments.

The results support a cognitive-motivational view, in which digital metacognition is the perceived ability of PPG teachers to plan, monitor, evaluate, and adapt their learning and academic self-efficacy is the confidence in facing academic challenges and maintaining the learning effort. The model theoretically links the cognitive processes accentuated in Self-Regulated Learning Theory to the motivational beliefs suggested in Social Cognitive Theory. At the practical level, teachers' professional education programmes should complement access to digital platforms with structured goal setting, reflective monitoring, strategy evaluation, constructive feedback, and progressively challenging learning activities. However, the study used a cross-sectional self-report design and thus, the findings are statistical connections within the present sample, and are not to be taken as evidence for temporal or causal relationships.

Practically, the Teacher Professional Education programme should not presume that the provision of learning management systems, electronic modules, video-conferencing platforms and digital evaluation systems is sufficient for the development of preparation for independent learning. The learning activities should enable participants to be able to set goals, assess progress, evaluate the learning tactics, reflect on challenges faced and change their approaches independently. At the same time, mastery experiences, positive feedback, modelling, gradual instructional support and more challenging assignments should enhance academic self-efficacy.

7. Limitations and Recommendations for Future Research

Several limitations should be considered when interpreting the findings of this study, and these limitations also point to directions for future research. First, the cross-sectional design does not capture changes in digital metacognition, academic self-efficacy, and self-regulated learning readiness over time and does not permit conclusions about temporal ordering or causality. Future studies could therefore employ longitudinal, experimental, or quasi-experimental designs to examine how these constructs develop over time and to evaluate the effects of specific learning interventions. Second, the study was limited to in-service teachers enrolled in the Indonesian Teacher Professional Education program, which may restrict the generalizability of the findings to other learner populations, educational levels, and institutional contexts. Future research should include more diverse samples across different educational settings. Third, the model did not incorporate potentially relevant contextual and individual variables, such as institutional support, digital literacy, technology-related anxiety, intrinsic motivation, and the use of artificial intelligence in learning. Including these variables may provide a more comprehensive explanation of differences in self-regulated learning readiness. Fourth, all constructs were measured using self-report questionnaires administered at a single point in time, which may introduce common method bias, social desirability bias, and consistency motives. Although the measurement and

structural models demonstrated satisfactory psychometric properties, method-related bias cannot be entirely ruled out. Future studies may therefore benefit from combining self-report measures with qualitative approaches, such as semi-structured interviews and focus group discussions, to explore teachers' learning experiences, expectations, technology-related anxiety, prior educational and school experiences, and other personal or contextual factors underlying academic self-efficacy. Such approaches may help explain why teachers with similar levels of digital metacognitive competence differ in their readiness for self-regulated learning.

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