



24 technology effectively into both teaching and assessment processes. Digital literacy,  
25 broadly conceived as the set of competencies that allow individuals to access,  
26 evaluate, create, and communicate information through digital technologies, has  
27 become central to teacher education in contemporary educational systems. Early  
28 conceptualizations of digital literacy highlighted skills such as accessing the internet,  
29 managing information, and communicating through digital networks, emphasizing its  
30 role in lifelong learning and professional practice.

31 For Master of Education (MEd) students, who occupy the dual role of advanced  
32 learners and aspiring professional educators, digital literacy is not merely an auxiliary  
33 skill but a core professional competence capable of influencing pedagogical decisions,  
34 evidence interpretation, and reflective assessment practice. However, much of the  
35 existing research on digital literacy among educators has focused on in-service  
36 teachers or undergraduate learners, often using self-reported measures that fail to  
37 capture the complexity of real-world application. This gap is critical, particularly for  
38 MEd students who engage with authentic professional teaching and assessment tasks  
39 where digital literacy interacts dynamically with pedagogical judgment and  
40 decision-making frameworks.

41 Moreover, the assessment of digital literacy has often been fragmented and instrument  
42 driven, lacking rich, multi-layered evidence that reflects the depth and breadth of  
43 competence dimensions. Traditional surveys, while useful for broad classification, do  
44 not reveal how digital literacy functions within authentic teaching and assessment  
45 contexts in teacher education programs. This represents a significant limitation in  
46 understanding both the nature of digital literacy and how it can be fostered  
47 systematically among future educators.

48 The primary purpose of this study is to investigate the digital literacy of MEd students  
49 through a multi-layer evidence-based research design. Specifically, the study aims to  
50 (1) identify core dimensions of digital literacy as they manifest in authentic  
51 educational tasks, (2) construct and apply a contextualized assessment framework  
52 capable of capturing multi-layer evidence, (3) evaluate the effectiveness of targeted  
53 intervention strategies, and (4) explore the interplays among technological proficiency,  
54 analytical capability, and reflective decision-making in professional practice. Through  
55 these objectives, the study seeks to contribute both conceptually and empirically to  
56 the literature on digital literacy and teacher education.

57 The significance of this study is threefold. Theoretically, it extends existing models of  
58 digital literacy beyond narrow skill-based perspectives to a construct encompassing  
59 professional reasoning and evidence-oriented competencies. Methodologically, it  
60 advances the use of multi-layer evidence approaches—integrating performance tasks,  
61 self-reports, and qualitative narratives—to comprehensively assess competence.  
62 Practically, the findings offer actionable insights for teacher educators and  
63 policymakers striving to prepare future teachers for digitalized learning environments.

## 64 **2. Literature Review**

### 65 **2.1 Conceptualizing Digital Literacy in Teacher Education**

66 Digital literacy has evolved from a simple focus on technology use to a complex  
67 construct encompassing cognitive, social, and pedagogical dimensions. Early research  
68 positioned digital literacy in the context of broader literacy debates, arguing that  
69 digital skills extend beyond technical know-how to include the ability to critically  
70 engage with digital content and tools. Foundational frameworks such as TPACK

71 (Technological Pedagogical Content Knowledge) and DigCompEdu articulate digital  
72 literacy as deeply integrated with pedagogical knowledge and teaching practices,  
73 rather than standing alone as a generic competence.

74 Paul Gilster's seminal definition of digital literacy—highlighting the ability to access,  
75 evaluate, and use digital information in ways that support lifelong learning—remains  
76 influential in educational research. Contemporary models build on this foundation by  
77 emphasizing analytical reasoning, pedagogical integration, and reflective decision  
78 making as core components of digital literacy in teacher education. Such models  
79 recognize that educators must not only operate technology but also interpret digital  
80 evidence, make instructional decisions, and adapt practices in response to evolving  
81 educational contexts.

82 In teacher preparation programs, digital literacy is thus conceptualized as  
83 multidimensional, involving technological proficiency, information and data literacy,  
84 pedagogical integration, and reflective capacity. These dimensions reflect the  
85 demands placed on educators in digitally mediated teaching environments, where  
86 evidence from learning technologies, assessment platforms, and classroom data must  
87 be interpreted and acted upon to support student learning.

## 88 **2.2 Contextualized Assessment of Digital Literacy**

89 Traditional approaches to assessing digital literacy often rely on self-report  
90 questionnaires and standard checklists, which, while useful for broad surveys, fail to  
91 capture how competence is applied in authentic professional tasks. Increasingly,  
92 researchers have advocated for contextualized assessments that align performance  
93 tasks with real-world teaching scenarios, enabling evaluators to observe digital

94 literacy as it unfolds in practice. A multi-layer evidence approach integrates diverse  
95 sources—including task outcomes, digital artifacts, survey measures, and reflective  
96 narratives—to provide a richer, more valid representation of competence across  
97 contexts.

98 In educational settings, contextualized assessment helps bridge the gap between  
99 theoretical constructs and observable performance. By embedding assessment tasks in  
100 authentic teaching and assessment scenarios, researchers can better understand how  
101 MEd students enact digital literacy, interpret learning evidence, and make pedagogical  
102 decisions.

### 103 **2.3 Digital Literacy Enhancement Interventions**

104 Empirical studies on digital literacy enhancement suggest that structured  
105 interventions—such as task-based learning modules, scaffolded digital projects, and  
106 reflective practice activities—can effectively improve digital competence among  
107 pre-service and in-service educators. Interventions grounded in real teaching tasks and  
108 supported by feedback cycles appear particularly effective in fostering deeper  
109 engagement with digital tools and pedagogical reasoning. However, many existing  
110 studies focus on technical skills or attitudes, with less attention to evidence-based  
111 analytical skills and reflective decision-making processes that are vital in professional  
112 practice. Integration of multi-layer evidence in intervention evaluation remains  
113 underexplored, particularly in MEd contexts.

### 114 **2.4 Research Gaps**

115 Despite the growing recognition of digital literacy as essential for teacher education,  
116 several gaps remain. First, there is limited research specifically targeting digital

117 literacy development among MEd students, a group positioned at the intersection of  
118 advanced study and professional preparation. Second, existing assessment  
119 frameworks lack integration of multi-layer evidence that captures the complexity of  
120 professional competence. Third, intervention studies often overlook the linkage  
121 between evidence interpretation, reflective decision-making, and sustained  
122 professional growth. This study addresses these gaps by proposing a contextualized,  
123 evidence-based model of digital literacy tailored to MEd student learning and  
124 practice.

### 125 **3. Methodology**

#### 126 **3.1 Research Design**

127 This study adopts a mixed-methods research design to investigate the digital literacy  
128 of Master of Education (MEd) students and to examine the effectiveness of  
129 evidence-based enhancement strategies. A mixed-methods approach was chosen  
130 because it allows for the integration of quantitative and qualitative data, providing a  
131 comprehensive understanding of digital literacy as a multi-layered professional  
132 competence. The quantitative component focuses on measurable indicators of digital  
133 literacy through contextualized assessment tasks and survey instruments, while the  
134 qualitative component captures the nuanced ways in which students engage with  
135 digital tools, interpret evidence, and apply reflective decision-making in authentic  
136 teaching and assessment scenarios. By combining these methods, the study not only  
137 evaluates students' competencies but also explores the underlying processes and  
138 mechanisms through which digital literacy is enacted and enhanced.

139 The research is organized around three interconnected objectives. First, it identifies

140 the core dimensions of digital literacy in the context of MEd students' professional  
141 tasks. Second, it develops and applies a contextualized assessment framework  
142 designed to capture multi-layer evidence across technological proficiency, analytical  
143 skills, and reflective decision-making. Third, it evaluates the impact of structured  
144 interventions on students' digital literacy, linking observed improvements to the  
145 mechanisms revealed through multi-layer evidence analysis. The integration of these  
146 components ensures that the study addresses both what MEd students can do digitally  
147 and how these skills are applied, interpreted, and improved in professional contexts.

### 148 **3.2 Participants and Sample**

149 The participants of this study consisted of 82 MEd students enrolled in the  
150 subject-specific teacher education program at a research-intensive university. All  
151 participants were in their second year of the program and had prior coursework in  
152 pedagogical theory, assessment practices, and educational technology integration. The  
153 selection of participants followed a purposive sampling strategy to ensure that the  
154 sample represented a range of teaching disciplines, technological backgrounds, and  
155 prior digital experience. Ethical approval was obtained from the university research  
156 ethics committee, and all participants provided informed consent before participating  
157 in the study. To ensure anonymity and confidentiality, pseudonyms were assigned to  
158 participants during data collection and analysis.

159 The participants were distributed across different teaching specialties, including  
160 language education, mathematics, science, and social sciences, reflecting the diversity  
161 of the MEd program. This disciplinary variety allowed the study to examine how  
162 digital literacy manifests in different content-specific teaching and assessment

163 contexts. Demographic data, including age, gender, prior teaching experience, and  
164 self-reported digital proficiency, were collected through a background questionnaire,  
165 enabling descriptive analysis of the sample characteristics and ensuring that findings  
166 could be contextualized appropriately within the diverse cohort.

### 167 **3.3 Data Collection**

168 Data were collected through a combination of contextualized assignments,  
169 semi-structured interviews, and survey questionnaires, aligning with the multi-layer  
170 evidence framework of the study. The triangulation of multiple sources of data  
171 ensures both the validity and the richness of the findings.

172 Contextualized Assignments. Participants completed a series of digital teaching and  
173 assessment tasks designed to simulate authentic classroom scenarios. These tasks  
174 included creating lesson plans using digital tools, developing assessment items  
175 aligned with learning objectives, and analyzing student-generated data to inform  
176 pedagogical decisions. The assignments were structured to elicit evidence across  
177 multiple layers of digital literacy, including technological proficiency, evidence-based  
178 analytical skills, and reflective decision-making. Artifacts produced by students, such  
179 as lesson plans, assessment instruments, and data analysis reports, were collected and  
180 coded as part of the evidence base.

181 Semi-Structured Interviews. To capture students' cognitive and reflective processes,  
182 semi-structured interviews were conducted with a subset of 20 participants, selected  
183 to represent disciplinary diversity and varying levels of observed performance on the  
184 assignments. Interview questions probed students' reasoning behind digital tool  
185 choices, strategies for analyzing learning evidence, and reflections on how their

186 digital literacy influenced pedagogical decisions. Interviews were audio-recorded,  
187 transcribed verbatim, and subsequently analyzed to uncover patterns in students'  
188 engagement with digital tasks and interpretive reasoning.

189 Survey Questionnaires. A digital literacy survey was administered to all 82  
190 participants to measure self-reported proficiency and perceptions of competency in  
191 key digital literacy dimensions. The survey instrument was developed based on prior  
192 research in teacher digital literacy and adapted to the MEd context. It included items  
193 assessing technological proficiency, data analysis and interpretation, reflective  
194 decision-making, and confidence in applying digital tools in authentic teaching  
195 scenarios. Likert-scale responses were collected to enable quantitative analysis,  
196 providing a complementary perspective to the performance-based and qualitative  
197 evidence.

### 198 **3.4 Data Analysis**

199 Data analysis followed a multi-layer evidence approach, integrating quantitative and  
200 qualitative methods to provide a comprehensive evaluation of participants' digital  
201 literacy.

202 Quantitative Analysis. Survey responses and coded assignment scores were analyzed  
203 using structural equation modeling (SEM) to examine the relationships among core  
204 digital literacy dimensions. SEM enabled the testing of hypothesized paths between  
205 technological proficiency, evidence-based analytical skills, and reflective  
206 decision-making, providing insights into the latent structure of digital literacy and its  
207 interdependencies. Descriptive statistics, reliability analysis, and confirmatory factor  
208 analysis (CFA) were conducted to validate the measurement model prior to structural

209 modeling.

210 Qualitative Analysis. Interview transcripts and artifacts from assignments were  
211 subjected to content analysis to identify themes corresponding to the three layers of  
212 digital literacy. Coding was conducted iteratively, with initial codes derived from the  
213 conceptual framework and emergent codes added based on observed patterns. The  
214 analysis focused on how participants enacted digital literacy in authentic tasks, their  
215 strategies for interpreting learning evidence, and their reflective practices. Cross-case  
216 analysis allowed for the identification of disciplinary variations and commonalities in  
217 digital literacy enactment.

218 Multi-Layer Evidence Integration. The findings from quantitative and qualitative  
219 analyses were integrated to form a holistic understanding of digital literacy. This  
220 involved triangulating survey data, performance-based evidence, and interview  
221 insights to construct a multi-layer evidence matrix. The matrix maps participants'  
222 capabilities across technological proficiency, analytical reasoning, and reflective  
223 decision-making, providing a robust basis for explaining observed performance and  
224 informing targeted enhancement strategies. By synthesizing evidence across layers,  
225 the study captures both the structural dimensions of digital literacy and the  
226 mechanisms through which digital competence is enacted and developed in  
227 professional teaching contexts.

228 Overall, the methodology combines a mixed-methods research design, a purposive  
229 sample of 82 MEd students, multi-source data collection, and multi-layer evidence  
230 analysis. This design allows for a comprehensive investigation of digital literacy,  
231 bridging the gap between self-reported proficiency and authentic professional

232 performance. It also provides a strong foundation for evaluating interventions aimed  
233 at enhancing digital literacy, supporting both the explanatory and practical aims of the  
234 study.

## 235 **4. Results**

236 The results of this study are presented in three interconnected subsections: descriptive  
237 analysis of participants' digital literacy performance, structural relationships among  
238 core dimensions as revealed by structural equation modeling (SEM), and qualitative  
239 insights from contextualized assignments and interviews, which together form a  
240 multi-layer evidence interpretation of MEd students' digital literacy.

### 241 **4.1 Descriptive Analysis of Digital Literacy Performance**

242 Initial descriptive statistics were calculated to examine participants' performance  
243 across the three hypothesized dimensions of digital literacy: technological proficiency,  
244 evidence-based analytical skills, and reflective decision-making. On average,  
245 participants demonstrated moderate to high competence in technological proficiency,  
246 with a mean score of 4.1 out of 5 (SD = 0.52), reflecting familiarity with digital  
247 teaching tools, learning management systems, and online assessment platforms.  
248 Evidence-based analytical skills showed more variability, with a mean score of 3.7  
249 (SD = 0.61), indicating that while most students could manipulate and interpret digital  
250 data, some struggled to draw pedagogically meaningful conclusions from  
251 student-generated evidence. Reflective decision-making, which was measured  
252 through assignment narratives and interview responses, had a mean score of 3.9 (SD =  
253 0.58), suggesting that a majority of students could critically evaluate digital tools and  
254 adapt instructional strategies, though a smaller subset exhibited limited depth in

255 connecting reflections to broader pedagogical goals.

256 Performance patterns varied across disciplines. For example, students in language and

257 social science programs tended to excel in reflective decision-making and contextual

258 interpretation of data, whereas students in mathematics and science programs showed

259 stronger technological proficiency but less nuanced reflection on pedagogical

260 implications. These trends indicate that disciplinary conventions and prior exposure to

261 digital tools influence how MEd students enact digital literacy, highlighting the

262 importance of contextualized assessment that captures both domain-specific and

263 transferable competencies.

264 Table 1. Descriptive Statistics of Digital Literacy Dimensions (N = 82)

Dimension	Mean	SD	Min	Max
Technological Proficiency	4.10	0.52	3.0	5.0
Evidence-based Analytical Skills	3.70	0.61	2.5	4.8
Reflective Decision-Making	3.90	0.58	3.0	5.0

265 *Notes:* Scores range from 1 (low competence) to 5 (high competence).

## 266 4.2 Structural Relationships Among Digital Literacy Dimensions

267 To test the hypothesized interrelationships among the three dimensions, structural

268 equation modeling (SEM) was conducted using survey and performance-based data.

269 The measurement model demonstrated good fit indices ( $\chi^2/df = 2.14$ , CFI = 0.962,

270 TLI = 0.955, RMSEA = 0.051), confirming that the indicators reliably represented the

271 latent constructs. Confirmatory factor analysis validated the three-factor structure

272 corresponding to technological proficiency, evidence-based analytical skills, and  
273 reflective decision-making.

274 The structural model revealed statistically significant paths among the dimensions.  
275 Technological proficiency positively predicted evidence-based analytical skills ( $\beta =$   
276  $0.54, p < 0.001$ ), indicating that students who were more skilled in using digital tools  
277 were also more capable of analyzing and interpreting learning evidence effectively.  
278 Evidence-based analytical skills, in turn, significantly predicted reflective  
279 decision-making ( $\beta = 0.63, p < 0.001$ ), suggesting that the ability to extract  
280 pedagogically meaningful insights from digital data directly supports critical  
281 evaluation and adaptive instructional decisions. Additionally, a direct path from  
282 technological proficiency to reflective decision-making was also significant, though  
283 slightly weaker ( $\beta = 0.29, p < 0.01$ ), implying that familiarity with digital tools  
284 contributes to reflective practice not only indirectly via analytical skills but also  
285 directly through confidence and fluency in using digital resources.

286 Table 2. SEM Path Coefficients Among Digital Literacy Dimensions

Path	Standardized $\beta$	SE	$p$ -value
Technological Proficiency $\rightarrow$ Analytical Skills	0.54	0.08	<0.001
Analytical Skills $\rightarrow$ Reflective Decision-Making	0.63	0.07	<0.001
Technological Proficiency $\rightarrow$ Reflective Decision-Making	0.29	0.09	<0.01

287 *Model fit indices:*  $\chi^2/df = 2.14$ , CFI = 0.962, TLI = 0.955, RMSEA = 0.051.

288 *Notes:* All paths are statistically significant, confirming the interdependency among  
289 the three dimensions of digital literacy.

### 290 **4.3 Multi-Layer Evidence from Assignments and Interviews**

291 Complementing the quantitative SEM analysis, qualitative data from assignments and  
292 interviews provided rich evidence of how students operationalized digital literacy in  
293 authentic teaching and assessment scenarios. Task-based assignments revealed that  
294 students frequently leveraged multiple digital tools simultaneously—for instance,  
295 integrating learning management systems with automated quiz analytics and  
296 interactive presentation software to design and evaluate lessons. High-performing  
297 students demonstrated not only fluency in tool use but also sophisticated integration  
298 of evidence into lesson design. One participant in a science program, for example,  
299 described how she used real-time quiz analytics to adjust group tasks dynamically,  
300 thereby aligning instructional strategies with student comprehension levels.

301 Interviews offered insight into reflective decision-making processes. Participants  
302 articulated a clear awareness of the pedagogical rationale behind tool selection and  
303 data interpretation, often referencing previous teaching experiences or disciplinary  
304 conventions. Students who scored high on SEM analytical indicators were able to  
305 explain causal relationships between learning evidence and instructional adjustments,  
306 illustrating the mediating role of evidence-based analysis in bridging technological  
307 proficiency and reflective judgment. Conversely, participants with weaker analytical  
308 skills tended to use digital tools mechanically, without connecting outputs to  
309 meaningful pedagogical decisions, further confirming the SEM results on path  
310 significance.

311 Table 3. Multi-layer Evidence Matrix of Selected Participants

Participant	Technological Proficiency (Score/5)	Analytical Skills (Score/5)	Reflective Decision-Making (Score/5)	Key Observations from Assignments & Interviews
P01	4.8	4.5	4.7	Integrated LMS analytics and adaptive lesson planning; clear reflection on data-informed decisions.
P15	4.2	3.6	3.8	Effective tool use but limited depth in connecting analysis to pedagogy.
P28	3.9	4.0	4.1	Strong analytical interpretation; moderate technical proficiency.
P42	4.5	3.2	3.5	High tool fluency, low analytical and reflective depth; needs targeted intervention.

	Technological	Analytical	Reflective	Key Observations
Participant	Proficiency	Skills	Decision-Making	from Assignments & Interviews
	(Score/5)	(Score/5)	(Score/5)	
P61	4.0	3.8	4.0	Balanced proficiency; demonstrates ability to apply data insights to instructional design.

312 *Notes:* Matrix integrates quantitative scores with qualitative observations, illustrating  
313 multi-layer evidence of digital literacy in authentic tasks.

#### 314 **4.4 Observed Patterns Across Subgroups**

315 Further analysis examined patterns across subgroups defined by disciplinary  
316 background, prior teaching experience, and self-reported digital familiarity. Students  
317 with prior classroom teaching experience generally scored higher in reflective  
318 decision-making, supporting the notion that authentic teaching exposure strengthens  
319 the ability to interpret evidence and adapt instruction. Language and social science  
320 students tended to demonstrate stronger reflective skills, whereas science and  
321 mathematics students exhibited higher technological proficiency but moderate  
322 reflective capacities. These findings suggest that interventions should be tailored by  
323 disciplinary context to optimize digital literacy enhancement, rather than adopting a  
324 uniform approach across the entire cohort.

325 Overall, the results provide robust evidence supporting the multi-layer

326 conceptualization of digital literacy among MEd students. Quantitative SEM analysis  
327 confirmed statistically significant interdependencies among technological proficiency,  
328 evidence-based analytical skills, and reflective decision-making, while qualitative  
329 assignment and interview data illustrated the practical enactment of these dimensions  
330 in authentic educational contexts. The combination of statistical modeling and  
331 contextualized evidence demonstrates that digital literacy is both structured and  
332 dynamic, requiring integrated development of technical skills, analytical capabilities,  
333 and reflective judgment to achieve professional competence in modern teacher  
334 education.

## 335 **5. Discussion**

336 This study investigated the digital literacy of MEd students through a multi-layer  
337 evidence-based approach, integrating quantitative SEM analysis, task-based  
338 assessments, and qualitative interview data. The discussion synthesizes the findings,  
339 situates them within the existing literature, and explores theoretical and practical  
340 implications for teacher education in the digital era.

### 341 **5.1 Interpretation of SEM Results**

342 The structural equation modeling results demonstrated statistically significant paths  
343 among the three dimensions of digital literacy: technological proficiency →  
344 evidence-based analytical skills → reflective decision-making, with an additional  
345 direct path from technological proficiency to reflective decision-making. These results  
346 provide empirical support for a hierarchical and interdependent conceptualization of  
347 digital literacy, where proficiency with digital tools forms the foundation for  
348 higher-order analytical and reflective competencies.

349 The finding that technological proficiency strongly predicts analytical skills ( $\beta = 0.54$ ,  
350  $p < 0.001$ ) aligns with prior research suggesting that familiarity with digital tools is a  
351 prerequisite for effectively extracting and interpreting data in educational contexts  
352 (Ng, 2012; Martin & Grudziecki, 2006). Students who are fluent in digital  
353 environments can manipulate, organize, and visualize data efficiently, thereby freeing  
354 cognitive resources for deeper analytical reasoning. Moreover, the path from  
355 analytical skills to reflective decision-making ( $\beta = 0.63$ ,  $p < 0.001$ ) indicates that the  
356 ability to derive meaning from evidence is a critical mediator enabling informed  
357 pedagogical judgments. This result resonates with findings by Ferrari (2013) and  
358 Spante et al. (2018), who argued that digital literacy encompasses not only technical  
359 manipulation of tools but also the capacity to interpret digital evidence and make  
360 informed decisions within complex educational settings.

361 The direct, albeit weaker, path from technological proficiency to reflective  
362 decision-making ( $\beta = 0.29$ ,  $p < 0.01$ ) suggests that tool fluency can support reflective  
363 practice independently, particularly when students have prior pedagogical knowledge  
364 or experience. This underscores the notion that digital literacy is not merely a linear  
365 skill hierarchy but involves multiple overlapping pathways where technical, analytical,  
366 and reflective capacities interact dynamically. Collectively, the SEM results confirm  
367 that targeted development of technological proficiency alone is insufficient; analytical  
368 and reflective skills must be cultivated concurrently to achieve holistic digital  
369 competence.

## 370 **5.2 Insights from Multi-Layer Evidence**

371 The qualitative evidence from assignments and interviews complements and deepens

372 the quantitative findings. High-performing students integrated multiple digital tools,  
373 such as learning management systems, automated quiz analytics, and interactive  
374 presentation software, to design and evaluate teaching scenarios. These students not  
375 only demonstrated technical fluency but also effectively interpreted learning data to  
376 inform instructional decisions, reflecting the mediating role of analytical skills  
377 observed in the SEM model.

378 Conversely, participants with strong technological proficiency but weaker analytical  
379 abilities often used tools mechanically, without connecting outputs to meaningful  
380 pedagogical strategies. This gap highlights a common challenge in teacher education:  
381 students may acquire technical skills quickly, but the development of critical,  
382 evidence-based reflection requires guided practice and scaffolded learning  
383 experiences. These patterns echo the findings of Ng (2012) and Spante et al. (2018),  
384 emphasizing the need for contextualized assessment frameworks that capture  
385 competence across multiple dimensions rather than relying solely on self-reported  
386 proficiency.

387 The multi-layer evidence matrix (Table 3) illustrates these patterns systematically,  
388 showing how individual students' performance varies across technological, analytical,  
389 and reflective layers. The matrix provides actionable insights for educators, enabling  
390 the identification of students who require targeted interventions in specific dimensions.  
391 For example, students who score high in technological proficiency but low in  
392 reflective decision-making would benefit most from scaffolded reflection activities  
393 and guided interpretation of student data.

### 394 **5.3 Implications for Teacher Education**

395 The integrated findings have several implications for teacher education programs,  
396 particularly those preparing MEd students for digitally mediated teaching  
397 environments:

398 1. Curriculum Design: Teacher education curricula should embed  
399 multi-dimensional digital literacy development, integrating technical skill  
400 training, data interpretation exercises, and reflective practice assignments.  
401 Rather than teaching these competencies in isolation, programs should adopt  
402 task-based learning modules where students engage with authentic teaching  
403 scenarios that require simultaneous application of all three layers.

404 2. Assessment Strategies: Contextualized, multi-layer evidence assessments are  
405 critical to capturing the depth and interdependence of digital literacy.  
406 Traditional surveys or checklists are insufficient for evaluating professional  
407 competence. Incorporating performance-based assessments, digital artifact  
408 analysis, and reflective narratives allows educators to evaluate how students  
409 enact digital literacy in practice, providing richer evidence for feedback and  
410 improvement.

411 3. Targeted Interventions: SEM findings suggest that enhancing technological  
412 proficiency alone may not yield substantial gains in reflective decision-making.  
413 Therefore, interventions should specifically scaffold analytical reasoning and  
414 reflective practice. Examples include guided data analysis tasks, collaborative  
415 lesson planning using digital platforms, and structured reflective journals  
416 linked to classroom simulations.

417 4. Disciplinary Tailoring: Subgroup analyses indicated disciplinary differences;

418 for instance, social science students excelled in reflective decision-making,  
419 whereas STEM students demonstrated higher technological proficiency.  
420 Teacher education programs should consider disciplinary contexts when  
421 designing interventions, offering tailored activities that address the specific  
422 strengths and gaps of each cohort.

423 5. Professional Development and Lifelong Learning: The multi-layer framework  
424 reinforces the idea that digital literacy is dynamic and evolving. Teacher  
425 educators should instill habits of reflective practice and continuous  
426 engagement with emerging digital tools, aligning with Sustainable  
427 Development Goal 4 (quality education) and fostering lifelong learning  
428 competencies.

#### 429 **5.4 Theoretical Contributions**

430 This study extends current conceptualizations of digital literacy in several ways:

431 1. Multi-layer Framework: By empirically demonstrating the hierarchical and  
432 interdependent relationships among technological proficiency, analytical skills,  
433 and reflective decision-making, the study validates a multi-layer model of  
434 digital literacy for MED students. This advances prior models (Gilster, 1997;  
435 Ng, 2012) by situating analytical reasoning and reflective practice as core,  
436 measurable dimensions rather than peripheral competencies.

437 2. Integration of Multi-layer Evidence: Combining SEM with contextualized  
438 performance tasks and interviews provides a robust, evidence-based approach  
439 for evaluating digital literacy. This methodology addresses limitations in prior  
440 research that relied primarily on self-reports or technical assessments, offering

441 a template for future studies in teacher education.

442 3. Bridging Theory and Practice: The study connects conceptual models of  
443 digital literacy with observable professional behavior, demonstrating how  
444 theoretical constructs manifest in authentic educational tasks. This strengthens  
445 the validity and applicability of digital literacy frameworks in preparing future  
446 educators.

### 447 **5.5 Limitations**

448 Despite its contributions, the study has limitations. The sample was restricted to a  
449 single cohort of 82 MEd students, which may limit generalizability. Future research  
450 should replicate the multi-layer assessment framework across multiple institutions and  
451 diverse cultural contexts to validate its broader applicability. Additionally, the study  
452 focused primarily on short-term task-based interventions; longitudinal research is  
453 needed to explore the sustainability of digital literacy development over time. Finally,  
454 while SEM provided insights into interdependencies among dimensions, more  
455 complex models (e.g., latent growth modeling) could examine dynamic interactions  
456 and developmental trajectories of digital literacy in teacher education programs.

457 The findings of this study underscore the importance of conceptualizing digital  
458 literacy as a multi-layered, interdependent competence encompassing technological  
459 proficiency, evidence-based analytical skills, and reflective decision-making. SEM  
460 analysis confirmed the structural relationships among these dimensions, while  
461 multi-layer evidence from assignments and interviews illuminated their practical  
462 enactment in authentic teaching scenarios. For MEd programs, these insights highlight  
463 the need for contextualized assessments, integrated curriculum design, and targeted

464 interventions that foster holistic digital literacy development. By bridging theory,  
465 empirical evidence, and practical application, this study contributes to the ongoing  
466 evolution of teacher education in the digital era, equipping future educators with the  
467 skills necessary for effective, evidence-informed, and reflective practice.

468

## 469 **6. Conclusion**

470 This study explored the digital literacy of MEd students through a multi-layer,  
471 evidence-based framework, integrating technological proficiency, evidence-based  
472 analytical skills, and reflective decision-making. By combining SEM analysis with  
473 contextualized assignments and interviews, the study demonstrated that digital  
474 literacy is a dynamic, interdependent competence, where technical skills serve as the  
475 foundation, analytical reasoning mediates instructional decision-making, and  
476 reflective practice consolidates learning into pedagogically meaningful action. The  
477 results revealed statistically significant relationships among these dimensions,  
478 confirming the hierarchical yet overlapping structure of digital literacy, and  
479 highlighted how disciplinary background, prior teaching experience, and authentic  
480 task engagement influence students' performance.

481 The findings have important implications for teacher education programs. First,  
482 curriculum design should integrate multi-dimensional digital literacy development,  
483 combining technical training, data interpretation exercises, and reflective practice  
484 within authentic teaching scenarios. Second, assessment strategies should move  
485 beyond self-reports to incorporate multi-layer evidence, including performance-based  
486 tasks, digital artifacts, and reflective narratives. Third, targeted interventions should

487 scaffold analytical and reflective skills, particularly for students who demonstrate  
488 high technological proficiency but lower ability to interpret and apply data in  
489 pedagogical contexts. Finally, the study emphasizes the need for disciplinary tailoring  
490 and lifelong learning, ensuring that future educators are equipped to navigate  
491 increasingly complex digital teaching environments.

492 Theoretically, this research advances the conceptualization of digital literacy by  
493 demonstrating its multi-layered structure and providing empirical evidence of  
494 interdependencies among dimensions. Methodologically, it contributes a practical  
495 approach for multi-layer evidence collection and analysis that can be replicated in  
496 other higher education contexts. By bridging theory, empirical evidence, and practice,  
497 this study offers a robust foundation for enhancing the digital literacy of future  
498 teachers, ultimately supporting more effective, reflective, and evidence-informed  
499 teaching in the digital era.

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