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Effect of Digital Formative Assessment Framework on Students' Learning Trajectories in their Cognitive Domain at Higher Education Level

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ABSTRACT
The modern classrooms are transforming into digital classrooms bringing modern debates on assessment and student learning trajectories into light (Mukazi, 2022). The objective of this study was to implement a digital formative assessment framework and investigate the effect of digital formative assessment framework on students' learning trajectories in their cognitive domain at higher education level. The digital formative assessment framework used in the study is a 12-celled model framework based on William and Blake (2007) formative assessment strategies. The nature of the study was quantitative which followed the A-B-A research design of experimental studies. The data was collected from an intact group of master level studies, and analyzed by using statistical analysis techniques. Repeated measures ANOVA was applied to identify the effect of digital formative assessment framework on students learning trajectories in their cognitive domain. Results revealed that digital formative assessment was effective with an F-value of 537, p= 0.000 and a larger effect size (partial η^2 = .655). Results suggest that teachers may adopt technology integrated teaching strategies to foster better student outcomes.
Keywords: *Learning trajectory; cognitive domain; formative assessment*

INTRODUCTION
Implementation of digital formative assessment framework (DFA) effects the cognitive domain which encompasses the students' knowledge, comprehension, application , analyzing, evaluation and creating. Cogntive levels builds on other cognitive levels from basic recall to complex skills, for instance comprehension cognitive level advances from knowledge and so on (Anderson & Krathowhl, 2001). Adaptive nature of digital formative assessment strategies may enables the students to address their cognitive gaps which in return refine their learning strategies (Anderon et al. 2021). adaption of technological functionalities into teaching learning promotes learning from simple to complex one (Hughes & Rourke, 2020).

The assessment strategies has significantly transformed by integrating the digital technologies into educational practices. Digital formative assessment framework (DFA) have proved more crucial tool in education for enhancing the students learning in their cognitive domain with greater focus on formative assessment strategies by the provision of real time and personalized feedback (Evans et al., 2021). furthermore, digital formative assessment strategies are particular more helpful in supporting the students' cognitive domain as they allow students' continuous evaluation and reflection on their learning, which further facilitates them in deeper comprehension and skill acquisition (lai et al., 2020).

Results from recent studies suggest that incorporating technological functionalities in teaching learning process at higher education level can enhance the students learning in their cognitive domain by providing targeted feedback which supports students higher order thinking and problem solving skills. For instance, results from a study conducted by Lie and Xu (2020), revealed that digital formative assessment strategies when coupled with learning strategies, enhance the students' ability to analyze the concepts critically and apply knowledge into new situations. Furthermore, implementaion of AI based assessment tools has showed that cognitive growth increases as this offers adaptative learning experiences that align with students'

needs(Figueiredo et al., 2020).

As concern of the feedback in DFA, a study by Evans et al. (2021) has concluded that it significantly impact the students' achievement particularly in their cognitive domain. It further explained that timely feedback aligned with learning hypothetical trajectories has shown the improvements in learning outcomes and enhance deeper understanding. Moreover, questioning by teachers as well as by students in real time technological world can enhance students' metacognitive skills to solve higher order problems (Hwang et al., 2021).

As the adoption of digital learning technologies at higher education level, implementation of digital formative assessment frameworks can significantly be proven the means of advancements in assessment practices. A study on implementation of digital technologies at higher education level to improve the quality of education, described that digital formative assessment is effective to enhance academic success (Lai & Pratt, 2020). Liu and Xu (2020) further explain the importance of digital formative assessment frameworks for students' cognitive development by pairing technology with peer collaboration and self assessment strategies. Hoyles (2020) consider how the availability of digital technologies has allowed intended learning trajectories to be structured in particular forms and how these, coupled with the affordances of engaging mathematical tasks through digital pedagogical media, might shape the actual learning trajectories.

Much of the work has been done on use of digital formative assessment to enhance students' learning. Classroom assessment has a challenge to document the growth of learning of students (Thamrin, & Fahri, 2023). learning trajectory model is the solution to problem and teachers can be use in the classroom to monitor students learning. It has also stated that learning trajectories are spin of the classroom assessment (Heritage, 2010). Recognizing the limitations in how students communicate and interact in online learning environments, online teacher education course designers are challenged to identify and implement effective learning and assessment framework for teaching with technologies (Niess & Gillow-Wiles, 2020). Furthermore, it has also been observed technology-enabled, non-text feedback have significant role in creating positive digital discussion environment (i.e., audio, video and screencast feedback) (Little, Dawson, Boud, &Tai, 2023).

In online higher education, however, emphasis continues to be placed on summative assessment with formative assessment receiving little attention despite its crucial role in promoting learning (Pachler, 2020; Wang, 2021). For this reason, Pachler (2021) and Huang (2022) recommended a refocused emphasis on online formative assessment in order to create learner and assessment centered learning environments. Although there is a gap in how a digital formative assessment framework can be implemented to investigate its effect on students learning trajectories. Because student have different learning level and different points during a course of a study. Furthermore, the world is getting digitalize but the education system is Pakistan is still lacking in implementing digital formative assessment procedures within the classroom. In these situations, researcher was intended to implement the digital formative assessment framework to investigate its effect on the students' learning trajectories at higher education level.

Objectives of the study

Current study was design to:

1. Implement the digital formative assessment framework at higher education level.
2. Investigate the effect of digital formative assessment framework on students' learning trajectories in their cognitive domain at higher education level.

Research hypotheses

On the bases of the research objectives following null hypothesis were formulated:

H_o1: There are no identifiable patterns in students' learning trajectories in their cognitive domain at higher education level, across the intervention B and baseline phases (A1&A2)

H_o2: There will be no statistically significant effect of digital formative assessment framework on students' learning trajectories in their cognitive domain at higher education level.

H_o3: There will be no statistically significant difference between intervention period (B) and baseline period (A1) for students learning trajectories in their cognitive domain at higher

education level.

H_o4: There will be no statistically significant difference between baseline period A1 and baseline period A2 for students learning trajectories in their cognitive domain at higher education level.

H_o5: There will be no statistically significant difference between intervention period (B) and baseline period (A2) for students learning trajectories in their cognitive domain at higher education level.

RESEARCH METHODOLOGY

Present study was quantitative in nature and study was conceptualize from a positivistic theoretical paradigm. In this study researcher followed the A-B-A design of Experimental studies. In this design "A" represented the baseline period in which subjects were not receiving the treatment while "B" representing the intervention phase in which researcher implemented the digital formative assessment framework. Intervention phase was followed by another baseline period "A". An intact group E consisting of 32 students was selected to assess the effect of digital formative assessment framework on students learning trajectories. Researcher developed academic achievement tests for each phase of the study (i.e., for baseline and intervention phase). These tests were comprised of two sections (i.e., Multiple choice questions and short questions). There were 15 multiple choice questions based on remembering, understanding and application level of cognitive domain. While three short questions were developed for rest of three levels of cognitive domain. All these items were based on the content which were taught during the experiment. All the instrument were validated by language and subject specialists to measure their content validity index (CVI).

Table 1

Content Validity Indexes For each test

Experts	Contents Validity Index
Test 1	.88
Test 2	.88
Test 3	.88
Test 4	.88
Test 5	.89
Test 6	.89
Test 7	.89
Test 8	.89
Test 9	.89
Test 10	.89

Threats to internal validity of the study

There could be following possible threats to the internal validity of the study for using ABA single subject design. Although A-B-A single subject design provides good control over maturation, history and instrumentation threats to the internal validity of the study. But there could be a Conditions length threat which refers how long baseline and intervention conditions are in effect (Fraenkel, Wallen & Hyun, 2019). It is essential to gather enough data during each period to establish a clear pattern before moving to the next phase. Thus, researcher took minimum three tests during baseline periods of the study. While 4 academic achievements tests were taken during intervention period of the study as suggested by Fraenkel, Wallen and Hyun (2019) to maintain the stability of the data. Furthermore, tests were taken at equal intervals to control the threat of degree and speed of introducing and removing the intervention. Furthermore, digital

formative assessment framework was implemented in a sequence to control the threat of rapid change and mix of variables during intervention.

Reliability of the instruments

Cronbach's coefficient alpha values from the sample of the study for individual test were calculated to measure the reliability of the instruments which are given below:

Table

Reliability of the instruments

Academic achievement tests	Cronbach's Alpha
Baseline test 1	0.80
Basline test 2	0.83
Baseline test 3	0.85
Intervention test 1	0.85
Intervention test 2	0.82
Intervention test 3	0.84
Intervention test 4	0.85
Baseline test 4	0.80
Baseline test 5	0.80
Baseline 6	0.82

Study plan

The study was consisting of two phases i.e., planning phase and implementing phase. The whole process was validated through experts' view. Average content validity index of the plan is .87 which is according to the criteria set by Lynn (1986), a CVI of .83 or higher is considered acceptable for a panel of six to eight experts suggesting that the intervention plan is relevant as per the objectives of the study.

Planning phase

During a Planning phase researcher meet the students in a physical classroom in their institute. After brief introduction, researcher informed them about the teaching method and technologies to be used during course. Furthermore, researcher also asked them to have their active WhatsApp and e-mail accounts and install Poll Everywhere App in the systems (mobile phones and Laptop). A 60 minutes workshop on operating the app was also be provided by the researcher whose plan is given in table 2. Furthermore, researcher created a WhatsApp group with students.

Table 3

Workshop plan for the study

Sr. No.	Activities	Time Period
1	Introduction to the framework and the teaching learning technologies to be used	10 minutes
2	Presentation on functioning of poll everywhere App	30 minutes
3	Practice activity	10 minutes
4	Question and answer session	10 minutes

Implementation of the digital formative assessment framework

The implementation phase was consisting of a 12 celled framework. Which has been built on two strands; one of which is formative assessment strategies and other is digital functionalities strategies. Lesson plans were constructed on the basis content to be taught. The procedure to use the framework has been given below:

Cell 1A

1: Clarifying and Sharing Learning Outcomes and Success Criteria; A: Sending and Displaying

Learning outcomes which were called as hypothetical trajectory pertaining to course for lecture were sent to learners through WhatsApp at least one day prior to lecture. Later on, these hypothetical trajectories were displayed on the screen during lesson delivery on google meet or poll everywhere

Cell 1B

1: Clarifying and Sharing Learning Outcomes and Success Criteria; B: Processing and Analyzing

At the beginning of the lecture, researcher asked the students to review the hypothetical learning trajectories by using WhatsApp pole option providing an indication of how challenging they think hypothetical learning trajectories will be for them providing an indication of how challenging they think the learning outcomes will be for them.

Cell 1C

1: Clarifying and Sharing Learning Outcomes and Success Criteria; C: Interactive Environment

By using Google Docs option researcher asked the student to work together and prepare success criteria for a particular trajectory, which was shared in a WhatsApp group for later use.

Cell 2A

2: Classroom Discussion, Questioning, and Learning Tasks; A: Sending and Displaying

One day prior to lecture, researcher shared the hypothetical trajectories of that current lecture along with a small quiz to gather students' current understanding to the topic. Researcher began the lesson next day by sharing their results and discussed their knowledge gap which can be filled through the lesson.

Cell 2B

2: Classroom Discussion, Questioning, and Learning tasks; B: Processing and Analyzing

Following the above discussion researcher displayed a case study on the screen or a problem to be solved and asked the students to find best solution to the problem with reasoning within a specific provided time. After that time, according their students' numbers, researcher asked the student to provide the best solution only without justification. Meanwhile teacher created a poll to agree and disagree with the provided answer and results from the poll will also be shared

Cell 2C

2: Classroom Discussion, Questioning, and Learning Tasks; C: Interactive Environment

Having viewed poll results, now students were asked to provide a brief justification of their answer according to their student number. After that discussion researcher again asked them if any of the student would like to revise their original answers and finally concluded the lesson with her own remarks.

Cell 3A

Feedback; A: Sending and Displaying

At 3-4 days prior to lecture, researcher shared the hypothetical trajectories of that current lecture along with a proposed structure of forthcoming written assignment and presentation along with rubric to assess their assignment. Researcher assigned the topic to every student to work on by herself and list were shared on WhatsApp group and were shared on screen on their lecture day. Meanwhile every student were get at least 2 min audio containing personalized feedback specifically to his/her respective assignments' requirements to their phone number. Students were asked to think and search about the topic and enlist the needed questions about topic, structure and grading for their assignment along with the outline and draft of their assignment.

Cell 3B

Feedback; B: Processing and Analyzing

On the day of lecture, teacher asked every student to ask their questions and share their screen show their drafts and outlines of their assignments. Researcher provided those answers and feedback on their initial work. After that researcher overall highlighted the gaps, strength and weaknesses to work on to meet the prescribed performance criteria. This information allowed learners to compare and contrast their own personalized audio feedback against that given to the class at large.

Cell 3C

Feedback; C: Interactive Environment

Following the above feedback on their initial drafts and outlines, students were asked to submit their final assignments and related learning resources of their assignments on coming lecture day. That lecture day researcher were highlight the positive and negative points of their assignments. Students were also have opportunity to ask questions to improve their work. After having that feedback and answers they were asked to review their assignments and submit them again.

Cell 4A

4: Peer and Self-Assessment; A: Sending and Displaying

At least two days prior to the lecture, researcher formed pairs of students and they were asked to prepare a small objective type test (5 short questions) relevant to the content using Google Forms along with their answers/rubrics on previous lecture. Each partner shared their tests to attempt.

Cell 4B

4: Peer and Self-Assessment; B: Processing and Analyzing

Initially Students were asked to mark their own tests and after that they were asked to mark the attempted answers of their fellows according to their own rubric along with the explanation. It helped to them to understand the content with peers' perspective as they share the same learning needs

Cell 4C

4: Peer and Self-Assessment; C: Interactive Environment

Later on, results were shared and researcher opened the room for discussion to discuss some of their answers and seek feedback from their peers to learn where they are grappling with some of the questions. Even they would be allowed to disagree with the answer other have provide.

Table 4

Intervention Plan for the Study

Phases	Strategies and Functionalities	Duration
A	First Baseline period	Week 1
	Baseline test 1	Week 2
	Baseline test 2	Week 3
	Baseline test 3	Week 4
B	Intervention Period	
	1A: Clarifying and Sharing Learning Outcomes and Success Criteria; A: Sending and Displaying 1B: Clarifying and Sharing Learning Outcomes and Success Criteria; B: Processing and Analyzing 1C: Clarifying and Sharing Learning Outcome and Success Criteria; C: Interactive Environment	Week 5
	Intervention test 1	Week 6
.	2A: Classroom Discussion, Questioning, and Learning Tasks; A: Sending and Displaying 2B: Classroom Discussion, Questioning, and Learning tasks; B: Processing and Analyzing 2C: Classroom Discussion, Questioning, and Learning Tasks; C: Interactive Environment	Week 7
	Intervention test 2	Week 8
	3A: Feedback; A: Sending and Displaying 3B: Feedback; B: Processing and Analyzing 3C: Feedback; C: Interactive Environment	Week 9

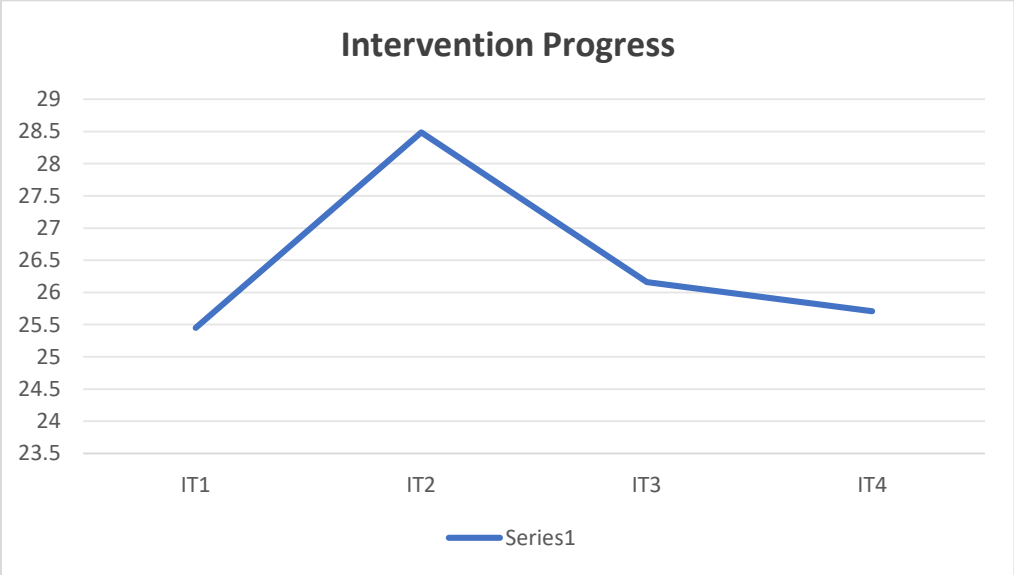
	Intervention test 3	Week 10
	4A: Peer and Self-Assessment; A: Sending and Displaying 4B: Peer and Self-Assessment; B: Processing and Analyzing 4C: Peer and Self-Assessment; C: Interactive Environment	Week 11
	Intervention test 4	Week 12
A	Baseline period	Week 13
	Baseline test 4	Week 14
	Baseline test 5	Week 15
	Baseline test 6	Week 16

Data analysis

Descriptive and inferential statistical analysis was done to attain the objectives of the study. Thus, descriptive analysis was done to track the trajectories in every domain to see the change during intervention phase while repeated measures ANOVA was applied to investigate the effect of digital formative assessment framework on students' learning trajectories.

Graph 1

Intervention Trajectory



Above graph 189 revealed the trajectory throughout the intervention period. It shows the students learning again the four assessment strategies and functionalities. Results shows that highest learning occurred when students were taught with Classroom Discussion, Questioning, and Learning Tasks; A: Sending and Displaying, B: Processing and Analyzing and C: Interactive Environment. Next best learning occur when students were taught with Feedback; A: Sending and Displaying, B: Processing and Analyzing C: Interactive Environment. Later on Peer and Self-Assessment; A: Sending and Displaying B: Processing and Analyzing, C: Interactive Environment, Clarifying and Sharing Learning Outcomes and Success Criteria; A: Sending and Displaying, B: Processing and Analyzing, C: Interactive Environment strategies respectively shows the progress.

Hence fore, on the basis of all above the graphs the null hypothesis $H_0 1$: There are no identifiable patterns in students' learning trajectories in their cognitive domain at higher education level, across the intervention B and baseline phases (A1&A2) is rejected.

Table 5

Results from Repeated Measure Annova

Descriptive statistics

Descriptive Statistics

Phases	Mean	Std. Deviation	N
Base line period A1	48.97	2.092	30
Intervention Period B	105.87	3.617	30
Baseline period A2	50.83	1.802	30

A Repeated Measure Annova was conducted to measure the impact of digital formative assessment (DFA) framework on students learning trajectories in their cognitive domain. This study was conducted in three phases to measure the impact of DFA. Results from the above table shows the highest mean score (M= 105.87) is obtain during intervention period B as compared to baseline period A1 (M= 48.97) and baseline period A2 (M=50.83) which emphasize on the effectiveness of digital formative assessment frame work.

Table 6: *ANOVA Summary Table for Repeated Measures*

Source	df	SS	MS	F	sig.	Partial η^2
DFA(within)	1.58	62697	39631	537	.000	.655
Error (within	45.8	338	7.3			

A Repeated Measure Annova was conducted to measure the effect of digital formative assessment (DFA) framework on students learning trajectories in their cognitive domain. The results indicated a significant effect of digital formative assessment framework on students' learning trajectories in their cognitive domain F= 537, p = .000, partial η^2 = .655. Which shows that null hypothesis H_o2: : There will be no statistically significant effect of digital formative assessment (DFA) framework on students learning trajectories in their cognitive domain.

Table 7: Post-Hoc Pairwise Comparisons of Phases

(I)DFA	(J) DFA	Mean Difference (I-J)	Sig.
Base line period A1	Intervention period B	-56.900*	.000
	Baseline period B	-1.867*	.000
Intervention	Baseline period A1	56.900*	.211
	Baseline period A2	55.033*	.211
Base line period B	Baseline period A1	1.867*	.000
	Intervention period B	-55.033*	.000

A Repeated Measure Annova was conducted to measure the impact of digital formative assessment (DFA) framework on students learning trajectories in their cognitive domain. Pairwise comparisons revealed that students' scores were significantly higher during intervention phase (M = 105.87, SD = 8.7) compared to both Baseline period 1 (M = (M= 48.97) and Baseline period 2 (M=50.83). results reveal that there was a statistically significant difference in students learning during intervention phase B and baseline period A2 (MD=56.900; MD=1.867; p=.000). Which leads to rejection of the hypothesis H_o5: There will be no statistically significant difference between intervention period (B) and baseline period (A2) for students learning trajectories in their cognitive domain.

Furthermore, results also revealed that was no statistically significant difference in baseline period A1 and baseline period A2 (MD=56.900; MD=55.033; p=.211) which leads to the acceptance of the hypothesis H_o4:There will be no statistically significant difference between baseline period A1 and baseline period A2 for students learning trajectories in their cognitive domain. Moreover, results also revealed that there was a statistically significant difference in students learning trajectories in their cognitive domain between baseline period A1 and intervention period B(MD=55.033; MD=1.867; p=.000). Which leads to the rejection of a null hypothesis H_o3: There will be no statistically significant difference between intervention period (B) and baseline period (A1) for students learning trajectories in their cognitive domain.

FINDINGS

The results of the study highlight the significant impact of the digital formative assessment framework on students' learning outcomes, particularly during the intervention phase (Period B). The highest level of learning was observed when students engaged in strategies such as Classroom Discussion, Questioning, and Learning Tasks, with specific emphasis on Sending and Displaying, Processing and Analyzing, and creating an Interactive Environment. These strategies were followed by feedback, peer and self-assessment, and clarifying/sharing learning outcomes, all of which contributed to noticeable learning progress. The statistical analysis revealed a substantial improvement in students' performance during the intervention phase (M = 104.8) compared to both baseline periods (A1: M = 48.97 and A2: M = 50.83). The intervention period demonstrated a significant cognitive impact, with the F-value of 537 and p-value of .000, indicating the effectiveness of the digital formative assessment framework. Pairwise comparisons confirmed that the students' learning scores were significantly higher during the intervention phase than at any baseline period. Additionally, the results indicated a statistically significant difference between the baseline periods A1 and A2 (p = .211), showing no substantial learning difference between these two phases. However, the comparison between baseline period A1 and intervention period B (MD=55.033, p=.000) emphasized the marked improvement in learning outcomes during the intervention phase, further supporting the efficacy of the digital formative assessment framework.

Conclusion

This study was conducted to implement a digital formative assessment framework (DFA) at higher education and to investigate its effects on students' learning trajectories in their cognitive domain. Results from the analysis revealed that there was a significant effect of digital formative assessment framework on students learning trajectories in their cognitive domain. Which explains that students trajectories showed jumps during intervention phase in their cognitive domain as compared to the baseline period. Furthermore, most of the improvements was observed when students were taught with classroom discussion and questioning technique of formative assessment framework with a particular focus on analyzing and processing technological functionality. Moreover results also revealed that difference between students' learning trajectories during both the baseline period was minimal which explains the effectiveness of the digital formative assessment framework during intervention phase. Hence this study demonstrates that digital formative assessment framework significantly improves the the students' learning trajectories in their cognitive domain. Thus, this suggests that teachers may prioritize the integration of technology with assessment techniques to fooster students learning. Teachers may create more interactive digital environment to ensure discussions, questioning and timely feedback.

References

Anderson, T., Garrison, D. R., & Archer, W. (2021). *The community of inquiry framework: A historical and contemporary review.* Journal of Online Learning Research, 7(2), 119-140.

Evans, C., Harding, N., & McCauley, S. (2021). *Digital formative assessment: Exploring its role in student engagement and learning outcomes in higher education.* Computers & Education, 163, 104092.

Figueiredo, R. A., Silva, M. C., & Simoes, A. R. (2020). *The impact of AI-driven assessment tools on student performance and feedback effectiveness.* Journal of Educational Computing Research, 57(6), 1499-1516.

Fraenkel, J., Wallen, N., & Hyun, H. (2019). How to Design and Evaluate Research in Education.

Hughes, J. E., & O'Rourke, D. (2020). *A conceptual framework for using digital formative assessment in higher education. Journal of Computer-Assisted Learning*, 36(3), 316-325.

Hwang, G. J., Wu, P. H., & Chen, C. H. (2021). *Integrating digital formative assessment with collaborative learning to enhance critical thinking in higher education.* Educational Technology Research and Development, 69(2), 249-266.

Lai, K. W., & Pratt, K. (2020). *Exploring digital formative assessment tools in higher education: The impact on student learning outcomes and engagement.* Educational Technology & Society, 23(4), 230-244.

Liu, M., & Xu, B. (2020). *Enhancing students' cognitive skills in higher education: The role of digital formative assessment and collaboration.* Computers & Education, 149, 103811.

Zhang, X., & Huang, R. (2021). *AI-based digital formative assessments and their impact on students' cognitive development in higher education. Journal of Educational Technology Systems*, 50(2), 162-179.

Thamrin, N. S., & Fahri, A. (2023). Enhancing Learning through Formative Assessment and Feedback.

Niess, M., & Gillow-Wiles, H. (2020). Developing asynchronous online courses: Key instructional strategies in a social metacognitive constructivist learning trajectory. *Journal of Distance Education*, *27*(1), 1-23.