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Barriers to Effective Learning: Examining the Influence of Delayed Feedback on Student Engagement and Problem Solving Skills in Ubiquitous Learning Programming

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Abstract

The rapid evolution of technology has reshaped the educational landscape, ushering in ubiquitous learning environments that provide learners with unparalleled access to educational resources at any time and location. This study aimed to investigate the impact of delayed feedback on student engagement and problem-solving skills in ubiquitous learning programming environments. The purpose was to understand how different forms of student engagement—behavioral, emotional, and cognitive—influence problem-solving abilities and how students perceive and handle delayed feedback. A quantitative approach, involving a cross-sectional survey design, was adopted. Data were collected from 293 students enrolled in the Department of Informatics and Computer Engineering, Faculty of Engineering, Makassar State University, who had taken Web and mobile programming courses. Standardized questionnaires were used to measure the variables. Quantitative data analysis included descriptive statistical analysis and structural equation modeling (SEM) using SmartPLS 4.0. The research results revealed that behavioral engagement (BE) significantly improves problem-solving skills and helps students better handle delayed feedback. Emotional engagement (EE) has the strongest influence on problem-solving abilities and responses to delayed feedback. Cognitive engagement (CE), while not directly enhancing problem-solving skills, significantly aids in the management of delayed feedback. These findings underscore the importance of fostering behavioral and emotional engagement to enhance problem-solving skills and mitigate the adverse effects of delayed feedback. Strategies such as gamification, real-time collaboration, and immediate feedback mechanisms are essential to improve learning outcomes in ubiquitous learning programming environments.

Keywords: Ubiquitous learning; delayed feedback; student engagement; problem-solving skills.

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1. Introduction

The rapid evolution of technology has reshaped the educational landscape, ushering in ubiquitous learning environments that provide learners with unparalleled access to educational resources at any time and location (Huang et al., 2024). This transition towards ubiquitous learning, characterized by continuous and seamless learning experiences, has the potential to enhance student engagement and foster higher-order thinking skills. However, challenges persist in optimizing these environments to maximize student engagement and promote the development of critical thinking and problem-solving skills, with delayed feedback identified as a significant barrier to effective learning (Zhu & Darun, 2023). Timely and constructive feedback is essential for maintaining student motivation, enhancing understanding, and supporting the development of critical thinking and problem-solving skills (Hsu and Wu 2023).

Numerous studies have investigated strategies for overcoming the challenges of delayed feedback in digital learning contexts. One promising approach is the integration of automated feedback systems that leverage artificial intelligence and machine learning algorithms to provide real-time personalized feedback to students (Annan et al., 2019; Fakhri et al., 2023). These systems analyze student interactions and performance data to generate immediate,

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tailored feedback, aiding students in promptly addressing learning gaps (Green & Chenarides, 2020). Additionally, peer feedback mechanisms have shown promise in enhancing learning outcomes by involving students in the evaluation process, and promoting collaborative learning and critical reflection (Loureiro et al. 2022).

Although automated and peer feedback mechanisms offer promising solutions, their implementation in ubiquitous learning environments presents several challenges (Rababa, 2021). The efficacy of AI-driven feedback depends heavily on the quality and quantity of data available as well as the sophistication of the algorithms used (Wang et al., 2021). Studies have highlighted the technical and ethical issues associated with the deployment of AI in education, such as data privacy concerns and algorithmic bias (Zhao et al., 2021). Additionally, the effectiveness of peer feedback relies on students' ability to provide constructive evaluations, which can vary according to their expertise and engagement levels (Wong et al., 2023). These challenges indicate that, while these feedback mechanisms are beneficial, there are still significant gaps in understanding how to optimize their implementation in ubiquitous learning contexts.

This study aimed to examine the influence of delayed feedback on student engagement and the development of higher-order thinking skills in ubiquitous learning programming environments. By investigating both the immediate and long-term effects of feedback timing, this study aims to identify effective strategies to mitigate the negative impacts of delayed feedback. The novelty of this study lies in its comprehensive approach to evaluating feedback mechanisms, integrating both automated and peer feedback, and assessing their implications for student engagement and cognitive development in a u-learning context. The research questions were as follows.

a. Is there any effect of student engagement on problem-solving tendencies?
b. Is there an effect of student engagement on problem-solving tendencies in terms of the lack of immediate feedback?

2. Method

This study employed a quantitative technique to explore the influence of delayed feedback on student engagement and problem-solving abilities in ubiquitous learning programming settings. The study's design was a cross-sectional survey, during which data were collected from students enrolled in a ubiquitous learning programming course at a single point in time. The design entailed administering standardized questionnaires to assess variables, such as feedback timing, student engagement, and higher-order thinking skills.

The subjects of this investigation were undergraduate students enrolled in the Department of Informatics and Computer Engineering, Faculty of Engineering, Makassar State University, who successfully completed web and mobile programming courses. The sample size was 293 individuals, in accordance with the criteria outlined by Issac and Michael (1971) and a sampling method that utilized a proportional random sampling distribution (Isaac & Michael, 1971).

The sample selection was conducted according to specific criteria or research objectives. The quantity of samples collected was determined using the Structural Equation Modeling (SEM) analysis technique, which usually requires a sample size of 100-200 (Ghozali, 2012) or 5-10 times the number of observation parameters (Hair et al., 2006).

Data collection techniques involving questionnaires are effective for acquiring quantitative data. The questionnaires used in this study were developed and customized based on research conducted by Li et al. (2023) to gather the opinions of participants on the impact of delayed feedback on student engagement and problem-solving abilities in Ubiquitous Learning Programming.

Table 1. Indicators of the questionnaire sheet in this study

No.	Variable	Statement
1	Behavioral Engagement (BE)	1-6
2	Cognitive Engagement (CE)	7-16
3	Emotional Engagement (EE)	17-25
4	Problem-Solving Tendency (PST)	26-33
5	Lack of Immediate Feedback	34-42

In this research, the researchers assessed the instrument’s construct validity. To evaluate construct validity, they utilized confirmatory factor analysis (CFA) using SmartPLS 4.0. To determine reliability, they applied the rules of

construct reliability (CR) and variance extraction (VE), where a construct or variable is considered reliable if it produces a CR value of ≥ 0.7 and a VE value of ≥ 0.5 (Hair, 2017).

Quantitative data analysis approaches encompass the application of descriptive statistical analysis in combination with structural equation modeling (SEM) using SmartPLS 4.0. In particular, SEM analysis was used to evaluate the impact of exogenous latent variables on endogenous latent variables. Undertaking SEM analysis entails fulfilling several prerequisites, including executing normality tests, such as univariate and multivariate normality tests, as well as multicollinearity tests.

Five variables were incorporated into the model tests: behavioral engagement, cognitive engagement, emotional engagement, problem-solving tendency, and the absence of immediate feedback. The PLS-SEM model was evaluated using two separate models: a measurement model and a structural model (Hair et al., 2019).

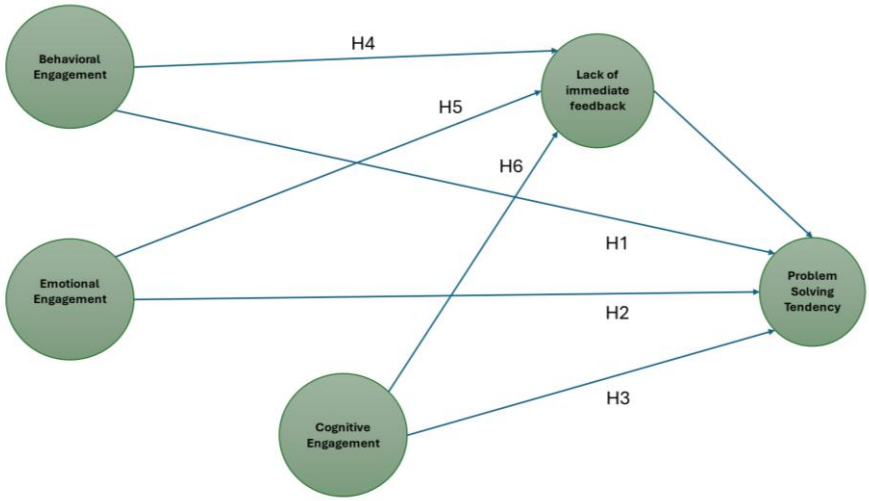

Figure 1. Framework of the study

The hypotheses of this study were as follows:

- H1: Behavioral engagement has a positive and significant effect on problem-solving tendencies.
- H2: Emotional engagement has a positive and significant effect on problem-solving tendencies.
- H3: Cognitive engagement has a positive and significant effect on problem-solving tendencies.
- H4: Lack of Immediate Feedback mediates the relationship between behavioral engagement and problem-solving tendencies with a positive and significant effect.
- H5: Lack of Immediate Feedback mediates the relationship between emotional engagement and problem-solving tendencies, with a positive and significant effect.
- H6: Lack of Immediate Feedback mediates the relationship between cognitive engagement and problem-solving tendencies, with a positive and significant effect.

3. Results and Discussion

3.1. Reflective Measurement Model Analysis

Figure 2 shows the structural path model that measures the relationship between various latent variables, including behavioral engagement (BE), Emotional Engagement (EE), Cognitive Engagement (CE), Lack of Immediate Feedback (LIF), and problem-solving tendency (PST). The model was used to identify and understand the direct and indirect effects of these variables.

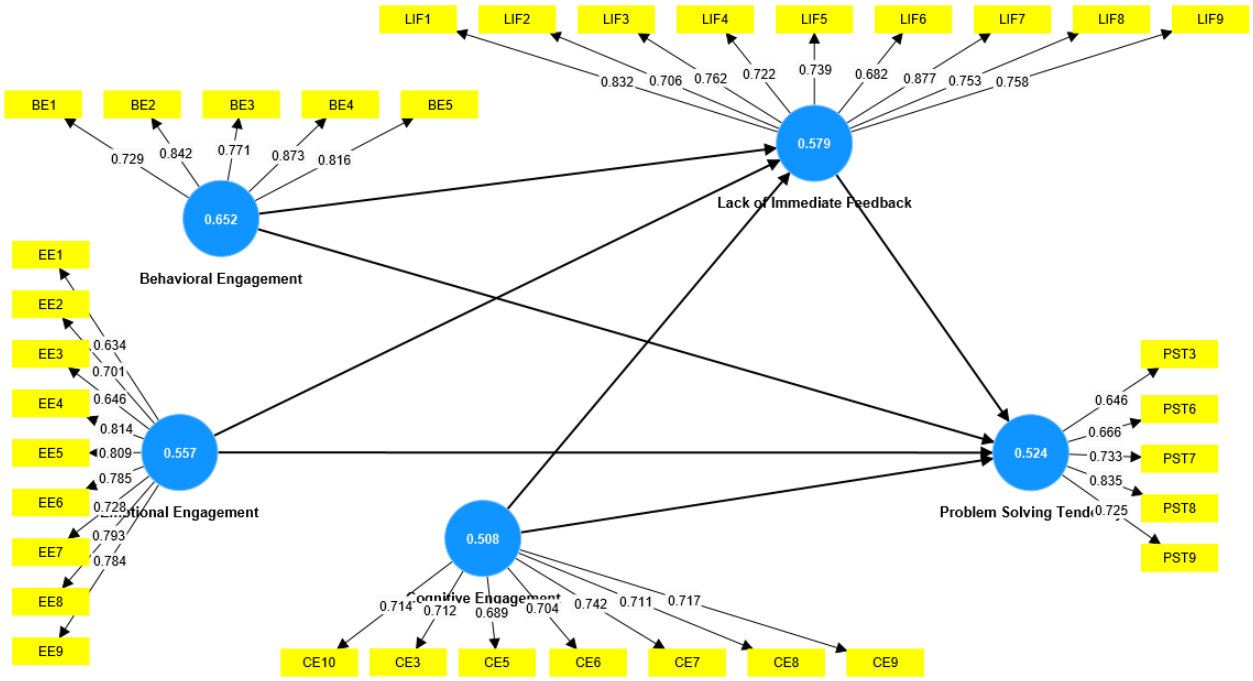

Figure 2. Outer Model

The results of the analysis of the reflective measurement model in Table 2 show that almost all outer loading values for each item/construct indicator from student assessment results are above the minimum value of 0.60; thus, the indicator is proven to be reliable (Hair, 2017). However, there are eight items with an outer loading of less than 0.5 (BE-6, CE-1, CE-2, CE-4, PST-1, PST-2, PST-4, and PST-5) (Hair Jr. et al., 2017). Furthermore, the internal consistency coefficient was found to be greater than 0.7. This indicates that the internal consistency coefficient is deemed acceptable, as it falls within the range of 0.7 0.9 (Nunnally Bernstein, 1994). Cronbach's alpha, Rho A, and composite reliability were also applied. The results indicated that all constructs were reliable based on composite reliability and Rho A values. Additionally, the analysis results in Table 2 show that all AVEs are greater than 0.50, which is the minimum value required to establish convergent validity. This indicates that the AVE value effectively explains more than half of the indicator variance (Hair Jr. et al., 2017).

Table 2. Reliability and Validity of the scale used

Construct	Item	Outlier Loadings	Cronbach's Alpha	rho_A	Composite Reliability	AVE
Behavioral Engagement (BE)	BE-1	0,729	0,866	0,871	0,903	0,652
	BE-2	0,842				
	BE-3	0,771				
	BE-4	0,873				
	BE-5	0,816				
	BE-6	Out				
Cognitive Engagement (CE)	CE-1	Out	0,845	0,858	0,878	0,508
	CE-2	Out				
	CE-3	0,712				
	CE-4	Out				
	CE-5	0,689				
	CE-6	0,704				
	CE-7	0,742				
	CE-8	0,711				
	CE-9	0,717				
	CE-10	0,714				
Emotional Engagement (EE)	EE-1	0,634	0,899	0,904	0,918	0,557
	EE-2	0,701				

Construct	Item	Outlier Loadings	Cronbach's Alpha	rho_A	Composite Reliability	AVE
	EE-3	0,646				
	EE-4	0,814				
	EE-5	0,809				
	EE-6	0,785				
	EE-7	0,728				
	EE-8	0,793				
	EE-9	0,784				
Problem-Solving Tendency (PST)	PST-1	Out	0,771	0,781	0,845	0,524
	PST-2	Out				
	PST-3	0,646				
	PST-4	Out				
	PST-5	Out				
	PST-6	0,666				
	PST-7	0,733				
	PST-8	0,835				
	PST-9	0,725				
Lack of Immediate Feedback (LIF)	LIF-1	0,832	0,908	0,910	0,925	0,579
	LIF-2	0,706				
	LIF-3	0,762				
	LIF-4	0,722				
	LIF-5	0,739				
	LIF-6	0,682				
	LIF-7	0,877				
	LIF-8	0,753				
	LIF-9	0,758				

Furthermore, in Table 3, under the Heterotrait-Monotrait coefficient (HTMT), all values in the table are consistently below 0.85, thus illustrating a clear separation among all constructs analyzed (Henseler et al., 2015). Thus, the constructs used in this study are valid, as they accurately measure what they are supposed to measure, and are reliable, producing consistent results.

Table 3. Heterotrait-monotrait ratio (HTMT)

	Behavioral Engagement	Cognitive Engagement	Emotional Engagement	Lack of Immediate Feedback	Problem Solving Tendency
Behavioral Engagement					
Cognitive Engagement	0,294				
Emotional Engagement	0,741	0,169			
Lack of Immediate Feedback	0,400	0,239	0,409		
Problem Solving Tendency	0,688	0,189	0,734	0,441	

3.2. Structural Model Analysis with Inner Model (Hypothesis Test)

Figure 3 presents a structural model that illustrates the interconnections between various types of engagement (behavioral, cognitive, and emotional engagement) and problem-solving tendencies, as well as the influence of Lack of Immediate Feedback. The numerical values on the arrow lines signify the path coefficients and p-values, which demonstrate the magnitude and importance of the relationships between the elements.

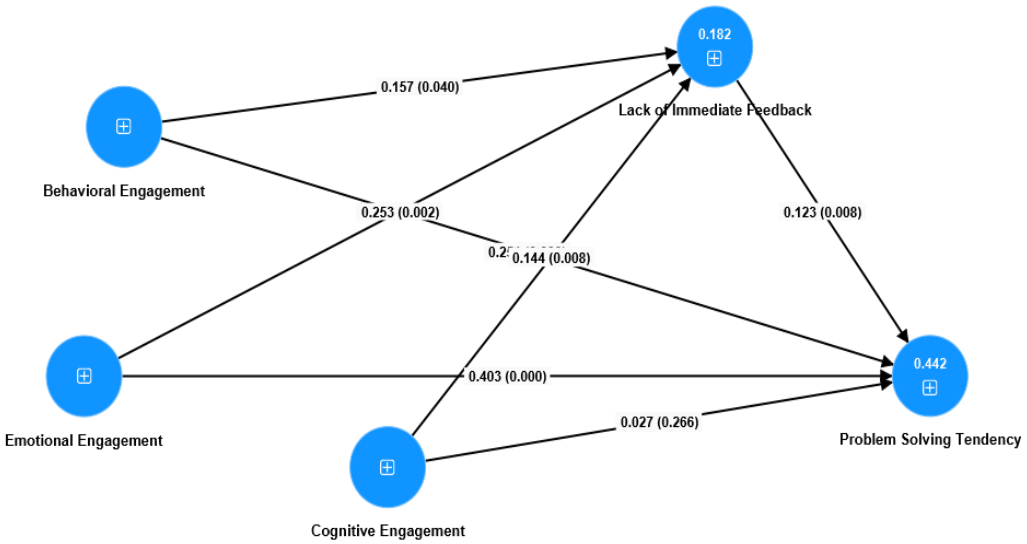

Figure 3. Inner Model

Table 4 shows the hypotheses of this study and the results obtained from the SEM analysis.

Table 4. Summary of Hypothesis Test Results

Table 4. Direct, indirect, and total effect of paths in the study model

Hypothesis	Path	Path Coefficient		
		Direct Effect	Indirect Effect	Total Effect
H1	BE -> PST	0,251***	0,019	0,271***
H2	EE -> PST	0,403***	0,031*	0,434***
H3	CE -> PST	0,027	0,018	0,045
H4	BE -> LIF	0,157*		0,157*
H5	EE -> LIF	0,253**		0,253**
H6	CE -> LIF	0,144**		0,144**

* p < .05, ** p < .01, *** p < .001
Note: BE, behavioral engagement; EE, emotional engagement; CE, cognitive engagement, PST, problem solving tendency, LIF, lack of feedback
Source: Own elaboration

The research framework in this study illustrates that different forms of engagement (behavioral, emotional, and cognitive) significantly influence problem-solving tendencies and immediate feedback.

First, behavioral engagement (BE) significantly affected problem-solving tendencies, with a direct effect coefficient of 0.251 (p<.001) and a minor indirect effect of 0.019. The total effect of behavioral engagement on problem-solving tendencies was 0.271 (p<.001), indicating that higher levels of behavioral engagement lead to better problem-solving abilities. Additionally, behavioral engagement significantly affects the lack of immediate feedback, with a direct effect coefficient of 0.157 (p<.05). This suggests that behavioral engagement plays a crucial role in how students perceive and handle the absence of immediate feedback.

Second, emotional engagement (EE) has the strongest influence on problem-solving tendencies among the three forms of engagement. The direct effect coefficient is 0.403 (p<.001), with an additional minor indirect effect of 0.031 (p<.05), resulting in a significant total effect of 0.434 (p<.001). This demonstrates that emotional engagement is vital for enhancing students' problem-solving skills. Emotional engagement also significantly impacts the lack of immediate feedback, with a direct effect coefficient of 0.253 (p<.01). This highlights the importance of emotional factors in how students respond to the absence of immediate feedback.

Lastly, cognitive engagement (CE) does not have a significant direct effect on problem-solving tendencies, with a direct effect coefficient of 0.027. However, it shows a minor indirect effect of 0.018, leading to a total effect

coefficient of 0.045, which is not statistically significant. Despite this, cognitive engagement significantly affects the lack of immediate feedback, with a direct effect coefficient of 0.144 ($p<.01$). This indicates that while cognitive engagement may not directly enhance problem-solving skills, it influences how students cope with the absence of immediate feedback.

The study highlights the significant role of behavioral and emotional involvement in enhancing problem-solving abilities, with emotional engagement playing the most substantial part. It also underscores the importance of these forms of involvement in how students manage the absence of immediate feedback, presenting valuable insights for educational strategies aimed at improving student engagement and learning outcomes.

3.3. Discussion

This study explored the influence of different forms of student engagement on problem-solving tendencies and the impact of immediate feedback in an educational setting. Structural equation modeling (SEM) analysis provided insights into the direct, indirect, and total effects of behavioral, emotional, and cognitive engagement on problem-solving abilities and lack of immediate feedback. The findings highlight the critical role of these engagement forms in enhancing students' problem-solving skills and responses to feedback mechanisms.

Behavioural engagement is an important factor in students' problem-solving skills and their ability to handle feedback effectively in an educational setting. The strong correlation between students' engagement levels and academic performance suggests that actively engaged students tend to exhibit better problem-solving skills (Taxipulati & Haidong, 2021). In addition, behavioural engagement affects how students perceive feedback delays. The importance of timely feedback to maintain students' motivation impacts their competence in managing delayed feedback without significant negative impact on their motivation or performance (Pan & Gan, 2019). Other research has also highlighted the importance of behavioural engagement in improving problem-solving skills and effectively managing feedback-related challenges (Escultura, 2023).

This research is supported by findings from (Gan et al., 2021), who highlighted the interrelationship between teachers' feedback practices, student motivation, and feedback behaviours in influencing learning outcomes. Highly engaged students can increase their intrinsic motivation to maintain their performance even with delayed feedback, emphasising the multifaceted impact of behavioural engagement on students' ability to navigate the feedback process effectively. Gao (Gao, 2023) emphasised the importance of students' conceptions of feedback in shaping their motivational beliefs and achievement goals. Meanwhile, (Aslam, 2021) explored the impact of learning motivation on academic achievement, highlighting the mediating role of constructive feedback in this relationship. Constructive feedback significantly influenced students' academic achievement through its impact on learning motivation, suggesting a close relationship between feedback, motivation and academic achievement (Câmpean, 2024). In summary, these studies underscore the critical role of behavioural engagement in shaping students' problem-solving abilities, feedback experiences, and overall academic performance.

Emotional engagement is a crucial factor in students' problem-solving abilities and their effectiveness in handling feedback processes in educational settings. Students who are emotionally invested are more likely to persist through challenges and solve problems effectively (Sajadifar, 2023). Our research aligns with these findings, highlighting the essential role of emotional engagement in nurturing strong problem-solving skills and driving better academic outcomes. Additionally, emotional engagement significantly impacts dealing with feedback delays. Positive emotions such as enjoyment and interest can sustain motivation and performance even without immediate feedback (Niu, 2024). Our study supports this by demonstrating that emotionally engaged students can effectively manage feedback delays, maintaining their motivation despite the absence of immediate reinforcement.

Furthermore, our research suggests that emotional engagement acts as a protective factor against the negative effects of feedback delays, contrasting with research by (Yang, 2024) that emphasis on the importance of timely feedback for sustaining motivation. Emotionally engaged students show resilience to disruptions in feedback due to their intrinsic motivation and emotional investment, enabling them to remain focused and committed. These insights underscore the value of fostering emotional engagement in educational environments, especially where immediate feedback may not always be feasible. Additionally, studies by (Liu, 2023; Niu, 2024) support the notion that emotional engagement significantly influences educational, psychological, and social outcomes, highlighting the comprehensive approach required to enhance student engagement effectively. By promoting emotional investment in learning, educators can create environments that support resilience, motivation, and a solid foundation for academic success.

Cognitive engagement, while not shown to significantly impact problem-solving tendencies in ubiquitous learning programming in our study, plays a crucial role in students' ability to handle delayed feedback effectively. This contrasts with broader literature, such as (Amalia, 2024), which often underscores the importance of cognitive engagement in academic success and problem-solving. The practical and iterative nature of programming tasks in ubiquitous learning environments may require more than just cognitive involvement to enhance problem-solving skills effectively. Research by (Stadler, 2024) supports our findings by indicating that cognitive strategies can assist students in managing learning processes, including coping with challenges like the absence of immediate feedback. The significant impact of cognitive engagement on managing feedback delays suggests that cognitively engaged students can employ effective learning strategies to mitigate potential frustration and demotivation caused by feedback lags.

While cognitive engagement may not directly enhance problem-solving abilities in programming, its role in helping students navigate feedback delays is crucial. This discrepancy highlights the intricate dynamics of different types of engagement in learning environments. Educators should consider integrating cognitive engagement with behavioral and emotional engagement to create a comprehensive learning experience. Encouraging activities that promote deep learning and strategic thinking can help students tackle the challenges of delayed feedback, supporting their overall learning process even if immediate problem-solving improvements are not directly observed. Furthermore, studies like (Amalia, 2024) on improving mathematical problem-solving skills using a contextual approach acknowledge that problem-solving is influenced by external factors beyond pure cognitive processes (Nong et al., 2023). This perspective aligns with our findings, suggesting that a holistic approach to problem-solving in programming education should consider a combination of cognitive, behavioral, and emotional engagement to address the multifaceted nature of learning and problem-solving tasks.

The importance of these findings lies in their implications for designing and implementing ubiquitous learning environments, particularly in programming education. Scientifically, this study enhances understanding of how different forms of engagement impact learning outcomes in technology-mediated settings, underscoring the need to foster emotional and behavioral engagement to boost problem-solving skills and mitigate delayed feedback's adverse effects. Practically, the results suggest that educators and instructional designers should prioritize strategies that enhance behavioral and emotional engagement, such as integrating gamification, real-time collaborative projects, and emotionally supportive features like immediate feedback and motivational messages. These strategies can effectively mitigate the negative impacts of delayed feedback, ensuring students remain motivated and perform well.

Furthermore, the findings advocate for developing more immediate and frequent feedback mechanisms, such as automated feedback tools and peer review systems, which can provide interim feedback and create a supportive learning community. Encouraging peer-to-peer interactions where students review and comment on each other’s work can foster collaborative learning and improve problem-solving skills. Addressing the barriers identified in this study can lead to more effective learning experiences and better educational outcomes in ubiquitous learning programming environments. By understanding and implementing strategies that enhance emotional and behavioral engagement and ensuring timely feedback, educators can create a more conducive learning environment that supports student success and satisfaction, optimizing educational technologies and teaching methodologies in the rapidly evolving landscape of ubiquitous learning.

Future research should consider conducting longitudinal studies to examine the long-term effects of different types of engagement—behavioral, emotional, and cognitive—on problem-solving skills and learning outcomes. This comprehensive approach could identify critical periods where specific interventions are most effective. Additionally, experimental studies that implement specific interventions aimed at enhancing engagement and providing immediate feedback can yield practical insights into effective teaching practices. Future research could focus on designing and testing these interventions in real-world classroom settings, assessing their impact on student engagement, problem-solving skills, and overall learning outcomes. Furthermore, with the increasing prevalence of technology in education, research should examine the potential of advanced technological interventions, such as artificial intelligence, virtual reality, and adaptive learning platforms, to enhance student engagement. Investigating how these technologies can be tailored to address the specific needs of students and mitigate the challenges associated with delayed feedback could significantly improve educational practices and outcomes.

4. Conclusion

This study elucidates the significant impact of delayed feedback on student engagement and problem-solving skills within ubiquitous learning programming environments. Our findings indicate that emotional engagement (EE) exerts

the strongest influence on problem-solving tendencies, emphasizing the necessity of fostering emotional investment in learning activities to enhance students' problem-solving abilities. Behavioral engagement (BE) also plays a critical role, particularly in how students cope with the absence of immediate feedback, highlighting the importance of active participation and interaction in maintaining motivation and performance despite delays. Cognitive engagement (CE), while not directly enhancing problem-solving skills, is essential in helping students manage the challenges posed by delayed feedback.

These insights suggest that educators and instructional designers should prioritize strategies that enhance emotional and behavioral engagement, such as incorporating gamification, real-time collaborative projects, and immediate feedback mechanisms. Additionally, implementing automated feedback tools and peer review systems can provide timely interim feedback, fostering a supportive learning community and improving problem-solving skills through collaborative learning. Addressing the barriers identified in this study can lead to more effective learning experiences and better educational outcomes in ubiquitous learning programming environments. By focusing on these engagement strategies and ensuring timely feedback, educational practices can be optimized, ultimately supporting student success and satisfaction in the rapidly evolving landscape of technology-mediated learning.

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