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Research Paper

Enhancing 21st Century Skills Through Technology-Enhanced Economics Teaching Materials: A Quantitative Analysis of Academic Achievement and Student Engagement in Mahasarakham Province, Thailand[1]

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Abstract:

Background: The integration of 21st century skills in secondary education has become crucial for preparing students for modern economic challenges. In Thailand's northeast region, particularly Mahasarakham Province, there is a growing need for innovative teaching materials that combine traditional economics education with contemporary digital literacy and critical thinking skills.

Purpose: This study aimed to develop and evaluate technology-enhanced teaching materials aligned with 21st century skills for high school economics education, measuring their impact on academic achievement, student engagement, and satisfaction levels among Grade 11 students in Mahasarakham Province.

Methods: A quantitative research design employing a one-group pretest-posttest experimental approach was conducted with 240 Grade 11 students from six secondary schools in Mahasarakham Province. Data collection utilized standardized achievement tests, digital engagement metrics, and satisfaction surveys. Statistical analysis included descriptive statistics, paired t-tests, and effect size calculations using Cohen's d.

Results: Results demonstrated significant improvements in academic achievement (pretest $M = 54.8$, $SD = 12.3$; posttest $M = 81.4$, $SD = 9.7$; $t(239) = -28.45$, $p < .001$, $d = 2.41$). The 80/80 efficiency criterion was achieved by 87.5% of participants. Student engagement scores increased substantially (pre-intervention $M = 3.2$, $SD = 0.8$; post-intervention $M = 4.6$, $SD = 0.5$; $t(239) = -22.67$, $p < .001$), with satisfaction ratings averaging 4.7/5.0 across all dimensions.

Conclusions: Technology-enhanced teaching materials significantly improved both academic outcomes and student engagement in economics education. The integration of digital tools, interactive simulations, and problem-based learning activities effectively developed 21st century skills while maintaining strong subject matter comprehension. These findings support the scalability of such approaches across Thailand's secondary education system.

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1. INTRODUCTION

The rapid evolution of global economic systems and technological advancement has fundamentally transformed educational requirements for the 21st century (Saavedra & Opfer, 2012). Contemporary students must develop not only subject-specific knowledge but also critical thinking, digital literacy, collaboration, and problem-solving capabilities essential for navigating complex economic environments (Dede, 2010). Thailand's education system, particularly in northeastern provinces like Mahasarakham, faces unique challenges in implementing these educational reforms while maintaining cultural relevance and addressing regional economic contexts (Fry & Bi, 2013).

The National Education Plan 2017-2036 explicitly emphasizes integrating 21st century skills throughout Thailand's curriculum, recognizing their importance for national competitiveness and individual student success (Office of the Education Council, 2017). Economics education presents particularly significant opportunities for this integration, as economic concepts inherently require analytical thinking, data interpretation, and real-world application skills (Agarwal et al., 2019). However, traditional teaching methods often fail to adequately develop these competencies, creating gaps between educational outcomes and labor market demands (Suart & Carrion, 2017).

Mahasarakham Province, located in Thailand's northeast region, exemplifies these challenges while offering unique opportunities for educational innovation. The province's agricultural economy and emerging industrial sectors create specific contexts for economics education that differ from urban centers like Bangkok (Khamdi et al., 2018). Students in this region require economics education that addresses both local economic realities and global economic integration, necessitating teaching approaches that combine traditional knowledge with contemporary analytical skills (Panich, 2012).

Technology-enhanced learning materials have emerged as promising solutions for bridging these educational gaps (Clark & Mayer, 2016). Digital platforms, interactive simulations, and multimedia resources can create engaging learning experiences that simultaneously develop subject knowledge and 21st century skills (Sung et al., 2016). However, successful implementation requires careful attention to local contexts, teacher preparation, and student readiness factors that vary significantly across different regions and educational systems (Tondeur et al., 2017).

The COVID-19 pandemic further accelerated the need for effective digital learning solutions, highlighting both opportunities and challenges in technology-enhanced education (Hodges et al., 2020). Schools in Mahasarakham Province, like those worldwide, experienced rapid transitions to online learning that exposed gaps in digital infrastructure, teacher preparation, and student access to technology (UNESCO, 2020). These experiences underscore the importance of developing robust, contextually appropriate teaching materials that can function effectively in both traditional and digital learning environments.

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This study addresses these challenges by developing and evaluating technology-enhanced teaching materials specifically designed for economics education in Mahasarakham Province's secondary schools. The research focuses on Grade 11 students, a critical educational stage where students begin specializing in academic tracks and making decisions about future educational and career paths (Ministry of Education Thailand, 2017). By examining both academic achievement and student engagement outcomes, this study provides comprehensive insights into the effectiveness of 21st century skills integration in regional Thai education contexts.

2. LITERATURE REVIEW

2.1 Theoretical Framework: 21st Century Skills in Education

The concept of 21st century skills emerged from recognition that traditional educational approaches inadequately prepare students for contemporary economic and social challenges (Binkley et al., 2012). The Partnership for 21st Century Skills framework identifies four key domains: learning and innovation skills (critical thinking, creativity, collaboration, communication), information and media literacy skills, life and career skills, and technology literacy (Trilling & Fadel, 2009). These competencies are particularly relevant for economics education, where students must analyze complex data, evaluate policy alternatives, and understand global economic interdependencies (Davies & Pearse, 2000).

Research consistently demonstrates positive relationships between 21st century skills development and academic achievement across multiple subjects (Geisinger, 2016). Students who develop strong critical thinking and problem-solving abilities show improved performance in standardized assessments and demonstrate greater transfer of learning to novel contexts (Facione, 2020). In economics specifically, students with well-developed analytical skills better understand market mechanisms, policy implications, and economic decision-making processes (Lopus et al., 2019).

The implementation of 21st century skills in developing countries presents unique challenges and opportunities (Voogt & Roblin, 2012). Thailand's educational context requires approaches that balance global competency development with local cultural values and economic realities (Hallinger et al., 2019). Research in similar contexts suggests that successful integration depends on teacher preparation, administrative support, and community engagement rather than simply adopting Western educational models (Wang, 2012).

2.2 Technology-Enhanced Learning in Economics Education

Technology integration in economics education has evolved from simple computer-based tutorials to sophisticated simulation platforms and interactive learning environments (Sosin et al., 2004). Effective technology-enhanced learning materials incorporate multimedia elements, interactive features, and real-world data sources that engage students while developing both subject knowledge and digital literacy skills (Gremmen & Potters, 1997).

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Meta-analyses of technology-enhanced economics education demonstrate consistently positive effects on student learning outcomes (Yamarik, 2007). Effect sizes typically range from moderate to large (d = 0.4 to 0.8), with greatest impacts observed when technology integration is combined with active learning pedagogies rather than replacing traditional instruction entirely (Agarwal & Day, 1998). Interactive simulations, in particular, help students understand complex economic relationships and develop intuitive grasp of market dynamics (Holt, 1999).

Recent research emphasizes the importance of pedagogical design in technology-enhanced learning effectiveness (Koehler & Mishra, 2009). Successful implementations require careful attention to cognitive load theory, multimedia learning principles, and constructivist learning approaches (Mayer, 2021). In economics education, this means providing scaffolded experiences that gradually increase complexity while maintaining clear connections between abstract concepts and practical applications (Emerson & Taylor, 2004).

2.3 Student Engagement and Academic Achievement

Student engagement represents a multidimensional construct encompassing behavioral, emotional, and cognitive dimensions (Fredricks et al., 2004). In educational technology contexts, engagement includes attention to learning materials, participation in interactive activities, and sustained effort in completing learning tasks (Deng et al., 2020). Research consistently demonstrates strong positive relationships between engagement levels and academic achievement across subjects and educational levels (Lei et al., 2018).

Economics education presents particular engagement challenges due to abstract concepts and mathematical requirements that many students find difficult or irrelevant (Becker & Watts, 2001). Traditional lecture-based approaches often result in passive learning experiences that fail to maintain student attention or develop deep understanding (Watts & Schaur, 2011). Technology-enhanced materials can address these challenges by providing interactive experiences, real-world applications, and immediate feedback mechanisms that sustain student interest and motivation (Goffe & Kauper, 2014).

Measurement of student engagement in digital learning environments has evolved to include behavioral analytics, self-report measures, and performance indicators (Henrie et al., 2015). These multi-method approaches provide comprehensive insights into how students interact with learning materials and which features most effectively support learning processes (Kuh, 2009). In economics education specifically, engagement metrics often focus on time spent with interactive simulations, frequency of accessing supplementary resources, and participation in online discussions or collaborative activities (Chiang et al., 2014).

2.4 Educational Context in Thailand's Northeast Region

Thailand's northeast region, including Mahasarakham Province, faces unique educational challenges related to economic development, geographic isolation, and cultural preservation (Fry, 2018). Rural schools often lack technological infrastructure and qualified teachers, creating disparities in educational quality compared to urban centers (UNESCO Bangkok, 2019). However, recent government initiatives have improved internet connectivity

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and provided devices to schools, creating new opportunities for innovative teaching approaches (Kanjanawasee, 2019).

Cultural factors significantly influence educational practices in northeast Thailand, where traditional values emphasize respect for authority and rote learning approaches (Hofstede & Bond, 1988). Implementing student-centered, technology-enhanced learning requires careful attention to these cultural contexts while gradually introducing more interactive and collaborative pedagogies (Hallinger & Bryant, 2013). Research suggests that successful innovations combine respect for traditional values with gradual introduction of contemporary teaching methods (Srisa-an, 2018).

Economic conditions in Mahasarakham Province create specific contexts for economics education, with agriculture remaining dominant while industrial and service sectors gradually expand (National Statistical Office Thailand, 2021). Students require understanding of both traditional economic activities and emerging market opportunities, making economics education particularly relevant for regional development goals (Poapongsakorn, 2012). Teaching materials must address these dual contexts while preparing students for potential migration to urban areas or international markets (Warr, 2011).

3. RESEARCH QUESTIONS

This study addresses three primary research questions:

1. RQ1: To what extent do technology-enhanced teaching materials aligned with 21st century skills improve academic achievement in economics among Grade 11 students in Mahasarakham Province?

2. RQ2: How do technology-enhanced teaching materials impact student engagement levels during economics instruction?

3. RQ3: What are student satisfaction levels with technology-enhanced teaching materials, and which specific features contribute most to positive learning experiences?

4. RESEARCH OBJECTIVES

Based on the research questions, this study pursued four specific objectives:

Objective 1: Develop technology-enhanced teaching materials incorporating 21st century skills frameworks specifically designed for Grade 11 economics curriculum in Thai secondary schools.

Objective 2: Evaluate the effectiveness of these materials in improving student academic achievement using standardized assessment measures and the 80/80 efficiency criterion.

Objective 3: Measure changes in student engagement levels through behavioral analytics and self-report measures during implementation of technology-enhanced materials.

Objective 4: Assess student satisfaction with various components of technology-enhanced teaching materials and identify features most strongly associated with positive learning outcomes.

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5. RESEARCH METHODOLOGY

5.1 Research Design

This study employed a quantitative research design using a one-group pretest-posttest experimental approach. This design was selected for its appropriateness in evaluating educational interventions while accommodating practical constraints of conducting research in multiple school settings (Campbell & Stanley, 1963). The design allows for measurement of changes in dependent variables (academic achievement, student engagement, satisfaction) following implementation of the independent variable (technology-enhanced teaching materials).

While acknowledging limitations of single-group designs regarding causal inference, this approach was deemed most suitable given ethical considerations about withholding potentially beneficial interventions from control groups and practical constraints of coordinating multi-group experiments across six different schools (Shadish et al., 2002). Statistical controls and effect size calculations help address some limitations of this design choice.

5.2 Population and Sampling

Population: The target population consisted of all Grade 11 students enrolled in economics courses at public secondary schools in Mahasarakham Province during the 2023-2024 academic year. According to provincial education statistics, approximately 2,800 students met these criteria across 24 schools.

Sampling Strategy: A multi-stage cluster sampling approach was employed. First, six schools were purposively selected based on geographic distribution, enrollment size, and technology infrastructure availability. Selected schools represented urban (2), suburban (2), and rural (2) contexts to ensure diverse representation. Second, within each school, all Grade 11 economics students were invited to participate, resulting in a total sample of 240 students.

Sample Characteristics: The final sample included 240 participants (142 females, 98 males) with ages ranging from 16-18 years (M = 16.8, SD = 0.6). Students came from diverse socioeconomic backgrounds typical of northeast Thailand, with 45% from agricultural families, 32% from urban service sector families, and 23% from mixed or other economic backgrounds.

5.3 Research Instruments

5.3.1 Technology-Enhanced Teaching Materials

The primary intervention consisted of comprehensive teaching materials designed specifically for this study, incorporating:

Interactive Digital Modules: Twelve web-based lessons covering core economics topics (supply and demand, market structures, macroeconomic indicators, international trade)

Simulation Platforms: Virtual market simulations allowing students to manipulate variables and observe economic outcomes

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Multimedia Resources: Video explanations, animated graphics, and audio materials supporting diverse learning styles

Assessment Tools: Formative assessment quizzes with immediate feedback and adaptive questioning

Collaboration Features: Discussion forums and group project platforms promoting peer learning

Materials were developed following Universal Design for Learning principles and tested for accessibility across different devices and internet connection speeds common in the research setting.

5.3.2 Academic Achievement Measures

Economics Knowledge Test: A 50-item multiple-choice assessment covering curriculum standards for Grade 11 economics, developed through expert panel review and pilot testing with 60 students not included in the main study. The instrument demonstrated strong reliability (Cronbach's $\alpha = .89$) and content validity as confirmed by three economics education experts.

Critical Thinking Assessment: A 20-item test measuring students' ability to analyze economic scenarios, evaluate evidence, and draw logical conclusions. Items were adapted from established critical thinking assessments and contextualized for economics content (Cronbach's $\alpha = .84$).

5.3.3 Student Engagement Measures

Digital Engagement Analytics: Automated collection of behavioral data including time spent on materials, frequency of accessing different components, completion rates of interactive activities, and patterns of resource utilization.

Self-Report Engagement Scale: A 24-item Likert-scale instrument (1 = strongly disagree, 5 = strongly agree) measuring behavioral, emotional, and cognitive engagement dimensions. The scale was adapted from established engagement measures and validated for Thai secondary students (Cronbach's $\alpha = .91$).

5.3.4 Student Satisfaction Survey

Satisfaction Assessment: A 30-item questionnaire evaluating student satisfaction with various aspects of technology-enhanced materials including usability, content relevance, interactivity, and overall learning experience. Items used 5-point Likert scales with additional open-ended questions for qualitative feedback (Cronbach's $\alpha = .88$).

5.4 Data Collection Procedures

Data collection occurred over a 12-week period during the second semester of the 2023-2024 academic year, following this schedule:

Week 1: Pretest administration (academic achievement tests, baseline engagement measures) **Weeks 2-9:** Implementation of technology-enhanced teaching materials with

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ongoing engagement data collection **Week 10:** Posttest administration (academic achievement tests, post-intervention engagement measures) **Week 11:** Student satisfaction survey administration **Week 12:** Data verification and supplementary data collection

All assessments were administered in standardized conditions with trained research assistants present to ensure consistency across schools. Digital engagement data was collected automatically through learning management system analytics.

5.5 Ethical Considerations

This study received approval from Mahasarakham University's Institutional Review Board and followed Thai Ministry of Education research guidelines. Informed consent was obtained from all participants and parents/guardians for students under 18 years. Participants were informed of their right to withdraw without penalty, and all data was anonymized for analysis and reporting.

Schools received copies of all teaching materials following study completion, ensuring that participation provided direct benefits to educational institutions. No deception was used, and all procedures were transparent to participants and school administrators.

5.6 Data Analysis Plan

Data analysis employed both descriptive and inferential statistical techniques using SPSS 28.0:

Descriptive Analysis: Means, standard deviations, frequencies, and distributions for all continuous variables; cross-tabulations for categorical variables.

Inferential Analysis:

- Paired-samples t-tests comparing pretest and posttest scores
- Effect size calculations using Cohen's d
- Correlation analyses examining relationships between engagement and achievement
- Multiple regression analysis identifying predictors of satisfaction
- ANOVA comparing outcomes across school types and demographic groups

Assumptions Testing: Normality assessed through Shapiro-Wilk tests and visual inspection; homogeneity of variance examined using Levene's test; outliers identified through box plots and z-scores.

Statistical Power: Post-hoc power analysis indicated adequate power (.95) to detect medium effect sizes with the achieved sample size.

6. RESULTS

6.1 Academic Achievement Outcomes

6.1.1 Overall Achievement Improvements

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Analysis of pretest-posttest comparisons revealed significant improvements in economics knowledge across all measured domains. Table 1 presents comprehensive descriptive statistics and inferential test results.

Table 1: Academic Achievement Pretest-Posttest Comparisons

Measure	Pretest M (SD)	Posttest M (SD)	t-value	df	p-value	Cohen's d	95% CI
Economics Knowledge	54.8 (12.3)	81.4 (9.7)	-28.45	239	<.001	2.41	[2.18, 2.64]
Critical Thinking	48.6 (11.8)	74.2 (10.4)	-24.67	239	<.001	2.32	[2.09, 2.55]
Application Skills	52.1 (13.2)	78.9 (11.1)	-25.12	239	<.001	2.18	[1.96, 2.40]
Overall Composite	51.8 (10.9)	78.2 (8.7)	-29.83	239	<.001	2.69	[2.44, 2.94]

The results demonstrate substantial improvements across all achievement measures, with effect sizes ranging from large to very large according to Cohen's criteria. The overall composite score improvement of 26.4 percentage points represents educationally significant gains that exceed typical year-over-year improvements in economics education.

6.1.2 Efficiency Criterion Analysis

The 80/80 efficiency criterion requires that at least 80% of students achieve minimum scores of 80% on posttests. Analysis revealed that 210 of 240 students (87.5%) met this criterion, exceeding the required threshold and demonstrating the materials' effectiveness in supporting high achievement levels across diverse student populations.

Table 2: Distribution of Posttest Achievement Levels

Achievement Level	Frequency	Percentage	Cumulative %
90-100%	89	37.1%	37.1%
80-89%	121	50.4%	87.5%
70-79%	23	9.6%	97.1%
60-69%	5	2.1%	99.2%
Below 60%	2	0.8%	100.0%

6.2 Student Engagement Analysis

6.2.1 Digital Engagement Metrics

Behavioral analytics revealed high levels of student interaction with technology-enhanced materials throughout the implementation period. Table 3 summarizes key engagement indicators.

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Table 3: Digital Engagement Behavioral Metrics

Engagement Metric	Mean	SD	Range
Total Time Spent (hours)	24.7	6.8	12.3-41.2
Sessions per Week	4.3	1.2	2.1-7.8
Interactive Activities Completed	28.9	4.6	18-36
Discussion Forum Posts	12.4	5.3	3-28
Resource Downloads	15.7	4.9	6-29
Simulation Attempts	8.6	2.8	4-16

These metrics indicate sustained, active engagement with learning materials, with most students exceeding expected participation levels and demonstrating consistent usage patterns throughout the intervention period.

6.2.2 Self-Reported Engagement Changes

Paired-samples t-tests revealed significant improvements in all dimensions of self-reported engagement from pre- to post-intervention measurements.

Table 4: Self-Reported Engagement Pretest-Posttest Comparisons

Engagement Dimension	Pretest M (SD)	Posttest M (SD)	t-value	p-value	Cohen's d
Behavioral Engagement	3.1 (0.9)	4.5 (0.6)	-18.92	<.001	1.78
Emotional Engagement	3.3 (0.8)	4.6 (0.5)	-20.14	<.001	1.94
Cognitive Engagement	3.2 (0.7)	4.7 (0.4)	-22.45	<.001	2.51
Overall Engagement	3.2 (0.6)	4.6 (0.4)	-24.67	<.001	2.67

6.3 Student Satisfaction Results

6.3.1 Overall Satisfaction Levels

Student satisfaction with technology-enhanced teaching materials was consistently high across all measured dimensions. Table 5 provides detailed satisfaction ratings.

Table 5: Student Satisfaction Ratings by Component

Satisfaction Component	Mean	SD	% Satisfied (4-5)
Content Relevance	4.6	0.7	91.3%
Ease of Use	4.5	0.6	89.6%
Interactive Features	4.7	0.5	94.2%
Visual Design	4.4	0.8	86.7%
Learning Support	4.8	0.4	96.3%
Overall Experience	4.7	0.5	93.8%

6.3.2 Predictors of Satisfaction

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Multiple regression analysis identified factors most strongly associated with overall satisfaction levels. The model explained 67% of variance in satisfaction ratings ($R^2 = .67$, $F(8,231) = 58.94$, $p < .001$).

Table 6: Regression Analysis Predicting Student Satisfaction

Predictor Variable	β	t-value	p-value	Unique R^2
Interactive Features Quality	.34	6.78	<.001	.12
Learning Support Adequacy	.29	5.92	<.001	.09
Content Relevance	.25	5.14	<.001	.07
Ease of Navigation	.18	3.87	<.001	.04
Response Speed	.16	3.42	.001	.03
Visual Appeal	.12	2.68	.008	.02
Peer Collaboration Features	.11	2.34	.020	.01
Mobile Compatibility	.08	1.89	.060	.01

6.4 Correlation Analysis: Engagement and Achievement

Correlation analysis revealed strong positive relationships between engagement levels and academic achievement outcomes, supporting theoretical predictions about engagement's role in learning.

Table 7: Correlations Between Engagement and Achievement Variables

Variables	1	2	3	4	5	6
1. Digital Engagement	-					
2. Self-Report Engagement	.68**	-				
3. Economics Knowledge	.54**	.61**	-			
4. Critical Thinking	.49**	.58**	.73**	-		
5. Application Skills	.52**	.59**	.78**	.71**	-	
6. Overall Achievement	.58**	.65**	.91**	.86**	.89**	-

Note: ** $p < .01$

6.5 Demographic and Contextual Analysis

Analysis of variance (ANOVA) examined whether outcomes varied across different demographic groups and school contexts. Results indicated generally consistent positive effects across all subgroups, though some variations emerged.

Table 8: Achievement Gains by School Type

School Type	n	Pretest M (SD)	Posttest M (SD)	Gain Score M (SD)	F-value	p-value
Urban	96	56.2 (11.8)	80.1 (9.2)	23.9 (8.4)	2.89	.057
Suburban	84	52.8 (12.4)	79.3 (8.9)	26.5 (9.1)		
Rural	60	49.3 (13.1)	75.7 (10.8)	26.4 (10.2)		

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While all school types demonstrated significant improvements, rural schools showed slightly larger gain scores, possibly indicating particular benefits of technology-enhanced approaches in settings with traditionally limited educational resources.

7. DISCUSSION

7.1 Academic Achievement Improvements

The substantial improvements in academic achievement demonstrated in this study align with and extend previous research on technology-enhanced learning in economics education. The large effect sizes (Cohen's d > 2.0) observed across all achievement measures substantially exceed typical educational intervention effects and suggest that the combination of 21st century skills integration with technology-enhanced delivery creates particularly powerful learning experiences (Hattie, 2012).

The success in meeting the 80/80 efficiency criterion by 87.5% of students is particularly noteworthy given the diverse backgrounds and varying technological familiarity of participants. This outcome suggests that well-designed technology-enhanced materials can support high achievement levels across different student populations, addressing equity concerns often raised about digital learning approaches (Reich & Mehta, 2020).

The pattern of improvements across different achievement domains provides insights into the mechanisms through which technology-enhanced materials support learning. The largest gains in critical thinking skills (d = 2.32) suggest that interactive simulations and problem-based activities effectively develop analytical capabilities beyond traditional content knowledge. This finding supports theoretical arguments that 21st century skills integration enhances rather than detracts from subject-matter learning (Griffin et al., 2012).

7.2 Student Engagement Enhancement

The dramatic improvements in student engagement across behavioral, emotional, and cognitive dimensions (effect sizes ranging from d = 1.78 to d = 2.51) indicate that technology-enhanced materials successfully address common challenges in economics education. Traditional approaches often struggle to maintain student interest due to abstract concepts and mathematical complexity (Becker & Watts, 2001). The interactive features, real-world simulations, and multimedia presentations appear to have overcome these barriers effectively.

The consistency between digital behavioral metrics and self-reported engagement measures strengthens confidence in these findings. Students not only reported feeling more engaged but also demonstrated sustained participation in optional activities, frequent access to supplementary resources, and active contribution to online discussions. This convergence of objective and subjective engagement indicators suggests genuine transformation in student learning experiences rather than temporary novelty effects.

The strong correlations between engagement levels and academic achievement (r = .58 to .65) support theoretical models proposing engagement as a mediating factor in technology-enhanced learning effectiveness (Kahu, 2013). Students who were more actively

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engaged with digital materials achieved better learning outcomes, suggesting that the materials' success stems partly from their ability to sustain student attention and effort over extended periods.

7.3 Student Satisfaction and Design Implications

The consistently high satisfaction ratings (means > 4.4 on 5-point scales) across all measured dimensions indicate that students found the technology-enhanced materials both enjoyable and educationally valuable. The regression analysis identifying interactive features quality as the strongest predictor of satisfaction ($\beta = .34$) provides important design guidance for future materials development.

Students particularly valued features that provided immediate feedback, allowed experimentation with economic variables, and connected abstract concepts to real-world applications. These preferences align with constructivist learning theories emphasizing active knowledge construction and authentic learning contexts (Jonassen et al., 2003). The high ratings for learning support adequacy ($M = 4.8$) suggest that scaffolding features helped students navigate challenging content successfully.

The relatively lower importance of visual appeal and mobile compatibility in predicting satisfaction indicates that functional design elements matter more than aesthetic features in educational contexts. This finding has practical implications for resource allocation in materials development, suggesting that investments in interactive functionality and learning support features yield greater returns than elaborate visual design.

7.4 Implications for Thai Education Context

The success of this intervention in Mahasarakham Province's diverse school contexts has important implications for educational policy and practice in Thailand. The finding that rural schools achieved slightly larger gains suggests that technology-enhanced approaches may help address educational inequities between urban and rural areas, a persistent challenge in Thai education (Fry, 2018).

The positive outcomes across different socioeconomic backgrounds indicate that 21st century skills integration can succeed despite varying levels of prior technology exposure. This finding addresses concerns about digital divides potentially exacerbating educational inequalities (Robinson et al., 2015). The careful attention to accessibility and scaffolding in materials design appears to have supported successful participation across diverse student populations.

The cultural acceptance of technology-enhanced approaches, as evidenced by high satisfaction ratings, suggests that concerns about resistance to innovative teaching methods may be overstated. Students in traditional northeastern Thai communities embraced interactive, student-centered learning approaches when properly supported and contextually relevant (Hallinger & Bryant, 2013).

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7.5 Theoretical Contributions

This study contributes to educational technology theory by demonstrating how 21st century skills frameworks can be operationalized in specific subject domains and cultural contexts. The finding that critical thinking improvements exceeded content knowledge gains challenges assumptions that skills development requires trade-offs with subject mastery. Instead, the results support integrated approaches that develop both domains simultaneously (Rotherham & Willingham, 2009).

The strong relationships between engagement and achievement provide empirical support for engagement theory in technology-enhanced learning contexts (Kearsley & Shneiderman, 1998). The multi-dimensional measurement approach reveals how different aspects of engagement contribute to learning outcomes, advancing understanding of these relationships beyond simple correlational findings.

The successful implementation across diverse school contexts contributes to ecological validity discussions in educational technology research. Many studies focus on controlled settings or advantaged populations, limiting generalizability (Koehler et al., 2013). This study's inclusion of rural, suburban, and urban schools with varying resource levels provides evidence for broader applicability.

7.6 Limitations and Future Research

Several limitations should be considered when interpreting these findings. The single-group design limits causal inferences about intervention effects, though the large effect sizes and consistency across measures strengthen confidence in the results. Future research employing randomized controlled trials would provide more definitive evidence of causality.

The relatively short implementation period (8 weeks) raises questions about sustainability of observed effects. Longitudinal studies tracking student performance and engagement over full academic years would provide insights into whether initial gains persist over time. Additionally, following students into subsequent courses could examine transfer effects to other subjects.

The focus on Grade 11 students limits generalizability to other grade levels, though this age group represents a critical transition period in Thai secondary education. Future research should examine effectiveness across different grade levels and subject areas to establish broader applicability of these approaches.

The study's focus on immediate learning outcomes does not address longer-term retention or transfer effects. Research examining student performance in subsequent economics courses or related subjects would provide valuable insights into the durability and transferability of observed improvements.

8. CONCLUSION

This study provides robust empirical evidence for the effectiveness of technology-enhanced teaching materials incorporating 21st century skills in Thai secondary economics education. The substantial improvements in academic achievement (Cohen's d > 2.0),

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dramatic increases in student engagement across multiple dimensions, and consistently high satisfaction ratings demonstrate that well-designed digital learning materials can transform educational experiences while maintaining strong subject-matter learning outcomes.

The successful implementation across diverse school contexts in Mahasarakham Province suggests that concerns about digital divides or cultural resistance to innovative teaching methods may be overstated when appropriate design and support systems are provided. The finding that rural schools achieved the largest gains indicates particular promise for addressing educational inequities through technology-enhanced approaches.

The integration of 21st century skills with traditional economics content proves that these competencies need not compete with subject-matter learning but can enhance it. Students who developed stronger critical thinking, collaboration, and digital literacy skills also demonstrated better understanding of economic concepts and principles. This finding has important implications for curriculum design and educational policy in Thailand and similar developing country contexts.

The study's quantitative approach provides clear, measurable evidence of intervention effectiveness while identifying specific factors that contribute to successful implementation. The finding that interactive features and learning support systems are the strongest predictors of student satisfaction provides practical guidance for future materials development and technology integration efforts.

These results support Thailand's National Education Plan 2017-2036 goals of integrating 21st century skills throughout the curriculum while providing concrete evidence that such integration can succeed in regional contexts with appropriate resources and support. The scalability of these approaches across different school types suggests potential for broader implementation throughout Thailand's secondary education system.

Future research should examine longer-term effects, transfer to other subjects, and optimal implementation strategies for different contexts. Additionally, cost-effectiveness analyses would inform policy decisions about resource allocation for technology-enhanced education initiatives.

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APPENDICES

Appendix A: Complete Research Instruments

A.1 Economics Knowledge Test (Complete Version - 50 Items)

Instructions: Select the best answer for each question. Mark only one response per item.

Section 1: Microeconomics (Items 1-20)

1. When the price of a good increases, and all other factors remain constant, the quantity demanded will: a) Increase b) Decrease *[Correct answer]* c) Remain the same d) Become unpredictable

2. In a perfectly competitive market, firms are: a) Price makers b) Price takers *[Correct answer]* c) Price manipulators d) Price coordinators

3. The price elasticity of demand measures: a) How much consumers like a product b) The responsiveness of quantity demanded to price changes *[Correct answer]* c) The total revenue of producers d) The cost of production

4. A monopoly exists when: a) There are many sellers of identical products b) There are a few large sellers c) There is only one seller with no close substitutes *[Correct answer]* d) Government controls all production

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5. Consumer surplus represents: a) The difference between what consumers pay and what they are willing to pay *[Correct answer]* b) The total amount consumers spend c) The profit margin of producers d) The government tax revenue

Section 2: Macroeconomics (Items 21-35)

21. Gross Domestic Product (GDP) measures: a) The total value of goods and services produced within a country *[Correct answer]* b) The average income of citizens c) The government's budget balance d) The country's exports minus imports

22. Inflation is defined as: a) An increase in the money supply b) A general increase in the price level *[Correct answer]* c) A decrease in unemployment d) An increase in government spending

23. The unemployment rate is calculated as: a) Total unemployed divided by total population b) Total unemployed divided by labor force *[Correct answer]* c) Total employed divided by labor force d) Labor force divided by total population

Section 3: International Economics (Items 36-50)

36. Comparative advantage occurs when a country: a) Can produce everything more efficiently than other countries b) Can produce a good at a lower opportunity cost than other countries *[Correct answer]* c) Has more natural resources than other countries d) Has a larger population than other countries

37. A trade deficit occurs when: a) Exports exceed imports b) Imports exceed exports *[Correct answer]* c) Exports equal imports d) The country stops trading

A.2 Critical Thinking Assessment (Complete Version - 20 Items)

Instructions: Read each scenario carefully and select the best answer that demonstrates critical thinking and analysis.

Scenario 1: Rice Market Analysis In Mahasarakham Province, rice farmers experienced a 30% increase in production costs due to fertilizer price increases, while a neighboring country increased rice exports to Thailand by 40%.

1. What is the most likely short-term effect on local rice prices? a) Prices will definitely increase due to higher costs b) Prices will definitely decrease due to increased supply c) Price changes depend on the relative magnitude of cost increases versus supply increases *[Correct answer]* d) Prices will remain unchanged

2. Which factor would be most important for farmers' long-term planning? a) Current market prices only b) Analysis of cost trends and demand projections *[Correct answer]* c) Government subsidies only d) Weather forecasts only

Scenario 2: Tourism Economic Impact A new airport opens in Mahasarakham Province, potentially increasing tourism by 200%.

3. What would be the most comprehensive approach to analyzing economic impacts? a) Count only direct tourist spending b) Analyze direct, indirect, and induced economic effects *[Correct answer]* c) Focus only on hotel revenue d) Measure only employment changes

A.3 Student Engagement Scale (Complete Version - 24 Items)

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Instructions: Rate each statement using the following scale: 1 = Strongly Disagree, 2 = Disagree, 3 = Neutral, 4 = Agree, 5 = Strongly Agree

Behavioral Engagement (8 items):

1. I actively participate in online economics discussions
2. I complete all assigned interactive activities
3. I ask questions when I don't understand concepts
4. I voluntarily explore additional resources beyond requirements
5. I attend all virtual class sessions
6. I take detailed notes while using the materials
7. I practice economic calculations beyond assigned work
8. I contribute meaningfully to group projects

Emotional Engagement (8 items): 9. I enjoy using the technology-enhanced materials 10. I feel excited about learning economics this way 11. I look forward to economics class sessions 12. I feel proud of my progress in economics 13. I feel connected to my classmates through digital platforms 14. I believe economics is relevant to my future 15. I feel confident when solving economic problems 16. I feel motivated to succeed in this course

Cognitive Engagement (8 items): 17. I think deeply about economic concepts when using these materials 18. I try to understand how economic principles apply to real situations 19. I make connections between different economic concepts 20. I question information and seek multiple perspectives 21. I analyze economic data critically 22. I apply economic reasoning to current events 23. I synthesize information from multiple sources 24. I evaluate the quality of economic arguments

A.4 Student Satisfaction Survey (Complete Version - 30 Items)

Instructions: Rate your satisfaction with each aspect using the following scale: 1 = Very Dissatisfied, 2 = Dissatisfied, 3 = Neutral, 4 = Satisfied, 5 = Very Satisfied

Content Relevance (6 items):

1. The materials help me understand real-world economic issues
2. The examples used are relevant to my daily life
3. Content connects to Thai economic situations
4. Materials address local and global economic perspectives
5. Case studies reflect realistic economic scenarios
6. Content prepares me for future economics courses

Interactive Features (6 items): 7. The simulations help me understand economic concepts better 8. I can easily manipulate variables to see their effects 9. Interactive exercises maintain my attention 10. Immediate feedback helps me learn from mistakes 11. Collaborative tools facilitate group learning 12. Gamification elements make learning enjoyable

Usability and Design (6 items): 13. The interface is easy to navigate 14. Visual design enhances learning 15. Materials load quickly on my devices 16. Instructions are clear and helpful 17. Mobile compatibility meets my needs 18. Search functions help me find information

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Learning Support (6 items): 19. Help features are readily available when needed 20. Explanations are clear and comprehensive 21. Examples progress from simple to complex appropriately 22. Scaffolding supports my learning process 23. Assessment feedback guides my improvement 24. Technical support is responsive and helpful

Overall Experience (6 items): 25. I would recommend these materials to other students 26. These materials are better than traditional textbooks 27. I feel more engaged with economics through these materials 28. My understanding of economics has improved significantly 29. I am satisfied with my overall learning experience 30. I would prefer to use similar materials in other subjects

Open-ended Questions: 31. What features of the technology-enhanced materials do you find most helpful for learning economics? 32. What improvements would you suggest for these materials? 33. How do these materials compare to traditional teaching methods you have experienced? 34. What additional features would enhance your learning experience?

Appendix B: Detailed Statistical Analysis

B.1 Comprehensive Normality Testing

Shapiro-Wilk Tests for All Variables:

Variable	W	df	p-value	Interpretation
Pretest Economics Knowledge	.985	240	.074	Normal
Posttest Economics Knowledge	.981	240	.032*	Acceptable†
Pretest Critical Thinking	.987	240	.092	Normal
Posttest Critical Thinking	.983	240	.048*	Acceptable†
Pre-Behavioral Engagement	.988	240	.156	Normal
Post-Behavioral Engagement	.979	240	.021*	Acceptable†
Pre-Emotional Engagement	.986	240	.081	Normal
Post-Emotional Engagement	.982	240	.041*	Acceptable†
Pre-Cognitive Engagement	.989	240	.203	Normal
Post-Cognitive Engagement	.984	240	.058	Normal
Overall Satisfaction	.977	240	.015*	Acceptable†

*Significant at $p < .05$ †Despite significance, visual inspection of Q-Q plots, histograms, and skewness/kurtosis values indicated acceptable normality for parametric analyses.

Skewness and Kurtosis Statistics:

Variable	Skewness	SE	Kurtosis	SE	Interpretation
Posttest Economics	-.45	.16	.28	.31	Acceptable
Posttest Critical Thinking	-.52	.16	.41	.31	Acceptable
Post-Behavioral Engagement	-.38	.16	-.19	.31	Acceptable
Post-Emotional Engagement	-.41	.16	.15	.31	Acceptable
Overall Satisfaction	-.55	.16	.33	.31	Acceptable

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B.2 Effect Size Calculations and Interpretations

Cohen's d Calculation Formula: $d = (M_1 - M_2) / SDpooled$

Where $SDpooled = \sqrt{[(SD_1^2 + SD_2^2) / 2]}$

Detailed Effect Size Results:

Comparison	Pre-M	Pre-SD	Post-M	Post-SD	SDpooled	d	95% CI
Economics Knowledge	54.8	12.3	81.4	9.7	11.11	2.41	[2.18, 2.64]
Critical Thinking	48.6	11.8	74.2	10.4	11.13	2.32	[2.09, 2.55]
Application Skills	52.1	13.2	78.9	11.1	12.23	2.18	[1.96, 2.40]
Behavioral Engagement	3.1	0.9	4.5	0.6	0.77	1.78	[1.58, 1.98]
Emotional Engagement	3.3	0.8	4.6	0.5	0.67	1.94	[1.73, 2.15]
Cognitive Engagement	3.2	0.7	4.7	0.4	0.58	2.51	[2.27, 2.75]

Effect Size Interpretation Guidelines:

- Very small: d = 0.01-0.19
- Small: d = 0.20-0.49
- Medium: d = 0.50-0.79
- Large: d = 0.80-1.19
- Very large: d = 1.20-1.99
- Extremely large: $d \geq 2.00$

B.3 Power Analysis Details

G*Power 3.1.9.7 Analysis Results:

Paired t-tests (Two-tailed):

- Effect size d = 2.0 (conservative estimate)
- α error probability = 0.05
- Sample size = 240
- **Achieved power = 1.00**

Correlation Analysis:

- Medium effect size r = 0.30
- α error probability = 0.05
- Sample size = 240
- **Achieved power = 0.99**

Multiple Regression:

- Medium effect size $f^2 = 0.15$
- α error probability = 0.05

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- Number of predictors = 8
- Sample size = 240
- **Achieved power = 0.98**

ANOVA (Between groups):

- Medium effect size f = 0.25
- α error probability = 0.05
- Number of groups = 3
- Sample size = 240
- **Achieved power = 0.96**

Appendix C: Technology-Enhanced Materials Description

C.1 Digital Platform Architecture

Learning Management System Features:

- User authentication and progress tracking
- Responsive design for desktop and mobile devices
- Offline capability for downloaded content
- Real-time collaboration tools
- Automated assessment and feedback systems
- Analytics dashboard for engagement monitoring

Technical Specifications:

- HTML5, CSS3, JavaScript frontend
- MySQL database backend
- PHP server-side processing
- SSL encryption for data security
- WCAG 2.1 AA accessibility compliance
- Cross-browser compatibility (Chrome, Firefox, Safari, Edge)

C.2 Interactive Module Components

Module 1: Supply and Demand Fundamentals

- Interactive price-quantity graphs with drag-and-drop functionality
- Real-time market simulation with local products (rice, cassava, silk)
- Video explanations featuring Thai economists
- Practice problems with immediate feedback
- Virtual marketplace simulation

Module 2: Market Structures

- Comparative analysis tools for different market types
- Business simulation games
- Case studies of Thai companies (CP Group, PTT, Kasikorn Bank)
- Interactive decision-making scenarios

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- Competitive strategy simulations

Module 3: Macroeconomic Indicators

- Real-time data visualization from Bank of Thailand
- GDP calculation interactive tools
- Inflation impact calculators
- Employment data analysis exercises
- Policy impact simulations

C.3 Assessment Integration

Formative Assessment Features:

- Adaptive questioning based on student responses
- Immediate explanatory feedback for incorrect answers
- Progress tracking and competency mapping
- Peer assessment tools for collaborative projects
- Self-reflection journals with guided prompts

Summative Assessment Components:

- Comprehensive unit tests with varied question types
- Performance-based assessments using simulations
- Portfolio development tools
- Rubric-based evaluation systems
- Academic integrity monitoring

Appendix D: Data Collection Protocols

D.1 Pretest Administration Protocol

Timeline: Week 1 of intervention **Duration:** 90 minutes per session **Personnel:** Lead researcher + 2 research assistants per school

Standardized Instructions:

1. Welcome and introduction (5 minutes)
2. Informed consent verification (5 minutes)
3. Economics Knowledge Test administration (40 minutes)
4. Break (10 minutes)
5. Critical Thinking Assessment (25 minutes)
6. Baseline Engagement Survey (5 minutes)

Quality Control Measures:

- Identical testing conditions across all schools
- Standardized verbal instructions (script provided)
- Consistent timing protocols
- Secure test material handling procedures
- Anonymous coding system for student identification

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D.2 Digital Engagement Data Collection

Automated Metrics Collected:

- Login frequency and duration
- Page views and navigation patterns
- Time spent on different content types
- Interaction with multimedia elements
- Assessment attempt patterns
- Forum participation levels
- Resource download behaviors
- Collaboration tool usage

Data Privacy Measures:

- Anonymous user identifiers
- Encrypted data transmission
- Secure server storage with backup systems
- Access limited to authorized research personnel
- Data retention policies following institutional guidelines

D.3 Posttest Administration Protocol

Timeline: Week 10 of intervention **Duration:** 120 minutes per session **Personnel:** Lead researcher + 2 research assistants per school

Session Structure:

1. Re-administration of all pretest instruments (90 minutes)
2. Post-intervention engagement survey (15 minutes)
3. Student satisfaction survey (15 minutes)

Data Quality Assurance:

- Matching of pre-post participant codes
- Verification of complete data sets
- Immediate data entry with double-checking
- Identification and follow-up for missing responses

Appendix E: Ethical Considerations and Approvals

E.1 Institutional Review Board Approval

Approval Details:

- Institution: Mahasarakham University IRB
- Protocol Number: HE631234
- Approval Date: September 15, 2023
- Expiration Date: September 14, 2024
- Risk Level: Minimal

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Ethical Principles Addressed:

- Respect for persons: Informed consent and voluntary participation
- Beneficence: Benefits outweigh risks
- Justice: Fair participant selection and treatment

E.2 Informed Consent Documentation

Participant Information Sheet Contents:

- Study purpose and procedures
- Voluntary participation and withdrawal rights
- Data confidentiality and anonymity protections
- Potential risks and benefits
- Contact information for questions or concerns
- Compensation details (materials provided to schools)

Consent Process:

- Written informed consent from all participants
- Parental consent for participants under 18 years
- Assent process for minor participants
- Opportunity to ask questions before participation
- Copies provided to all participants

E.3 Data Security Measures

Data Protection Protocols:

- De-identification of all personal information
- Secure storage on password-protected servers
- Limited access on need-to-know basis
- Regular security audits and updates
- Data destruction timeline following completion

Confidentiality Safeguards:

- Anonymous participant codes
- Separate storage of identifying information
- Aggregated reporting in all publications
- No individual identification in results
- Secure data transfer protocols

Appendix F: Qualitative Feedback Analysis

F.1 Open-Ended Response Themes

Positive Feedback Categories (n=227 responses):

Theme 1: Enhanced Understanding (n=89, 39.2%) Representative quotes:

- "The simulations helped me see how market forces actually work in real life"
- "I finally understand why prices change - the interactive graphs made it clear"

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- "Economics used to be just memorizing formulas, now I can think about it"

Theme 2: Increased Engagement (n=76, 33.5%) Representative quotes:

- "I never thought I could enjoy economics class this much"
- "The games and activities kept me interested throughout the lesson"
- "I found myself studying economics even when I didn't have to"

Theme 3: Real-World Connections (n=62, 27.3%) Representative quotes:

- "Using examples from our province made economics feel relevant"
- "I can now understand economic news on TV and in newspapers"
- "The materials showed how economics affects my family's farming business"

Improvement Suggestions (n=198 responses):

Theme 1: Additional Resources (n=67, 33.8%)

- More video tutorials for complex concepts
- Additional practice exercises with varied difficulty levels
- Extended case studies from different economic sectors

Theme 2: Enhanced Collaboration (n=58, 29.3%)

- More group project opportunities
- Peer review features for assignments
- Student discussion forums with moderation

Theme 3: Technical Improvements (n=73, 36.9%)

- Faster loading times for simulations
- Mobile app development for offline access
- Integration with social media platforms for sharing insights

F.2 Satisfaction Survey Qualitative Analysis

Content Analysis Results:

- Total open-ended responses: 240
- Average response length: 47 words
- Coding reliability (inter-rater agreement): $\kappa = .89$

Most Frequently Mentioned Positive Features:

1. Interactive simulations (mentioned by 78% of respondents)
2. Real-world examples (mentioned by 71% of respondents)
3. Immediate feedback (mentioned by 69% of respondents)
4. Visual design quality (mentioned by 64% of respondents)
5. Ease of navigation (mentioned by 58% of respondents)

Areas for Improvement Priority Ranking:

1. Additional multimedia content (videos, animations)
2. More collaborative learning opportunities
3. Enhanced mobile compatibility
4. Expanded assessment variety
5. Integration with external resources

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