

NLP-Powered Curriculum Material Generation for Multilingual Maritime Technical Education

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ABSTRACT

Maritime education instructors spend 60-70% of professional time developing curriculum materials rather than teaching, with 85% of technical maritime resources available only in English creating comprehension barriers for Indonesian students whose English proficiency averages IELP 1.0-2.0 levels insufficient for technical content understanding. This research presents the design and validation of natural language processing systems trained on maritime education corpora capable of automatically generating lesson plans, assessment questions, case studies, and learning materials while adapting content complexity to diverse learner English proficiency levels. Employing design science research methodology with qualitative stakeholder evaluation, the study engaged maritime educators (n=16), instructional designers (n=8), and students (n=20) through structured interviews examining content quality, pedagogical effectiveness, and usability. Transformer-based NLP architecture incorporating BERT models fine-tuned on IMO Model Courses, STCW requirements, and maritime technical manuals achieved 78% content quality ratings from expert evaluators while reducing material development time 62% from 12 hours to 4.5 hours per lesson. Thematic analysis revealed strong support for AI-assisted content generation, identifying critical themes of instructor workload reduction, content accessibility enhancement, and curriculum updating acceleration. Pilot implementation with 450 students across Navigation and Engineering departments demonstrated equivalent learning outcomes compared to manually-developed materials while enabling rapid curriculum adaptation to regulatory changes, contributing validated NLP architectures and empirical evidence supporting intelligent content development in technical maritime education contexts addressing instructor time constraints and multilingual accessibility challenges.

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1. Introduction

The accelerating evolution of maritime industry technology, environmental regulations, and operational practices creates persistent curriculum updating imperatives for maritime training institutions, yet instructor time constraints severely limit material development capacity as teaching faculty spend 60-70% of professional effort creating lesson plans, assessment instruments, case studies, and supporting resources rather than direct student instruction, pedagogical innovation, or professional development activities critical for maintaining educational quality [1]. This content development burden proves particularly acute in technical maritime education where specialized subject matter spanning naval architecture, marine engineering,

navigation systems, cargo operations, and safety management requires instructors to synthesize complex technical information from diverse sources including International Maritime Organization conventions, equipment manufacturer manuals, industry best practices, and emerging research literature, then transform this material into pedagogically appropriate learning resources accounting for student prior knowledge, language proficiency, and cognitive development levels [2].

Indonesian maritime academies face compounded content development challenges as approximately 85% of authoritative maritime technical resources exist exclusively in English despite Indonesian maritime students' average English proficiency measuring IELP 1.0-2.0 levels (equivalent to IELTS 4.0-5.0) creating substantial comprehension barriers when instructors directly utilize international materials without extensive translation, simplification, and localization efforts consuming additional preparation time [3]. Sekolah Tinggi Ilmu Pelayaran Jakarta, Indonesia's flagship maritime training institution employing 180+ teaching faculty across Navigation, Marine Engineering, and Maritime Business departments, exemplifies the curriculum content development challenges confronting maritime academies globally, with instructor surveys indicating average 12 hours weekly invested in lesson material preparation including lecture slide creation, practical exercise design, assessment question development, and supplementary resource compilation, substantially exceeding the 6-hour weekly preparation allocation specified in institutional workload policies and contributing to documented instructor burnout, limited pedagogical innovation, and delayed curriculum updating as content development demands overwhelm faculty capacity for adopting new teaching methodologies or integrating emerging maritime technologies into existing curricula [4].

The language accessibility challenge proves particularly severe in technical subjects where precise terminology, complex procedural descriptions, and regulatory compliance specifications resist simplification, forcing instructors to choose between utilizing authentic English-language industry resources that students struggle comprehending or investing substantial time translating and adapting materials into Indonesian with appropriate technical vocabulary development and scaffolded complexity progression supporting diverse learner proficiency levels [5]. Current approaches to curriculum content development at STIP Jakarta and maritime institutions globally rely predominantly on individual instructor effort with limited institutional support infrastructure, creating multiple inefficiencies including duplicated material development as multiple instructors independently create similar resources for parallel course sections, inconsistent quality and pedagogical sophistication across materials developed by instructors with varying instructional design expertise, delayed curriculum updates as time-constrained instructors postpone integrating new regulatory requirements or technological developments, limited accessibility for diverse learners as materials designed for average students inadequately accommodate below-average or advanced proficiency levels, and inadequate translation resources as institutional foreign language support centers lack maritime technical expertise for specialized content localization.

The fundamental research problem addresses the absence of intelligent content generation systems capable of automatically producing pedagogically sound, technically accurate, linguistically accessible maritime education materials from authoritative source documents while adapting complexity levels to diverse student English proficiency ranges and accommodating rapid curriculum updating requirements driven by regulatory evolution and industry transformation, all implemented within resource constraints limiting expensive human translation services or extensive instructional designer staffing. Specifically, this research investigates four interconnected questions: What natural language processing architectures and training approaches effectively generate maritime education content including lesson plans, assessment questions, and learning resources from technical source documents while maintaining pedagogical quality and factual accuracy? How can NLP systems adapt content complexity and language proficiency requirements to accommodate Indonesian maritime students' diverse English capabilities ranging from basic to advanced levels without compromising technical precision? What instructor workflows and interface designs enable faculty to efficiently utilize AI-generated content, providing necessary customization, quality assurance, and pedagogical adaptation while realizing substantial time savings compared to manual development? How do NLP-powered content generation systems impact instructor workload, curriculum quality, student learning outcomes, and institutional capacity for rapid curriculum adaptation when implemented in Indonesian maritime education contexts characterized by multilingual challenges and limited instructional support resources?

This research contributes significant theoretical and practical advances to natural language processing educational applications and maritime training pedagogy scholarship while addressing critical gaps in AI-assisted curriculum development literature. Theoretically, it extends NLP frameworks predominantly developed for general educational content or simple question generation into specialized technical maritime education requiring domain-specific terminology, procedural knowledge representation, regulatory compliance accuracy, and multilingual accessibility accommodating non-native English learners engaging with English-language source materials. Methodologically, it validates NLP system design approaches balancing automated

generation efficiency with instructor control and customization capabilities, avoiding both extremes of fully manual development overwhelming faculty or completely automated systems producing generic content lacking pedagogical nuance.

Practically, the research delivers immediately deployable NLP architectures supporting Indonesia's maritime education instructor capacity development while providing empirical evidence of AI-assisted content generation's impact on faculty workload, material quality, and curriculum responsiveness to industry evolution. The investigation employs mixed-methods design science methodology combining iterative NLP model development with comprehensive qualitative stakeholder evaluation through maritime educator interviews (n=16 representing Navigation, Engineering, and ECDIS departments), instructional designer consultations (n=8 providing pedagogical expertise), and student focus groups (n=20 evaluating generated content usability), analyzing perspectives through systematic thematic analysis to identify content quality dimensions, workflow integration requirements, learning effectiveness, and sustainable adoption strategies, ultimately informing evidence-based recommendations for NLP-enhanced curriculum development at scale across Indonesia's maritime training network supporting efficient material production enabling instructor focus on high-value teaching activities rather than time-consuming content creation tasks.

2. Research Method

This research employs design science research methodology combined with natural language processing model development protocols, creating a rigorous systematic approach particularly suited for developing and evaluating AI content generation artifacts that address identified organizational problems through iterative cycles of corpus preparation, model training, content generation, quality evaluation, and stakeholder validation, as established by Hevner et al.'s foundational framework adapted for NLP applications in educational contexts [6]. Design science methodology proves especially appropriate for curriculum content research where innovation success depends not only on NLP model technical performance metrics like BLEU scores or perplexity but critically on instructor usability perceptions, pedagogical quality assessments, student learning effectiveness, and demonstrated time savings requiring qualitative investigation alongside quantitative performance evaluation [7].

The research integrates NLP system performance metrics with comprehensive stakeholder assessment, recognizing that content generation platforms must satisfy diverse requirements spanning technical specialists evaluating linguistic quality, subject matter experts assessing factual accuracy, instructional designers measuring pedagogical soundness, instructors experiencing workflow changes, and students utilizing generated materials for learning [8]. The research population comprises three distinct stakeholder groups essential for holistic NLP content generation validation. The maritime educator group (n=16) includes senior lecturers and department heads across Navigation (n=6), Marine Engineering (n=6), and ECDIS/specialized training (n=4) departments representing diverse technical specializations, selected purposively for combined subject matter expertise and extensive content development experience enabling authoritative evaluation of AI-generated material accuracy, pedagogical appropriateness, and curriculum alignment.

Educator participants, averaging 14.3 years maritime teaching experience with varied backgrounds including former seafaring chief officers and chief engineers transitioning to academic careers and civilian technical specialists, provide validation credibility spanning practical maritime operations knowledge and theoretical instructional perspectives. Educators reported spending 10-15 hours weekly on content development representing 45-60% of total professional time, providing strong motivation for evaluating workload reduction technologies. The instructional designer group (n=8) encompasses curriculum development specialists, educational technology consultants, and assessment design experts employed by STIP Jakarta's academic development center or contracted as external advisors, selected to evaluate NLP-generated content's pedagogical quality dimensions including learning objective alignment, cognitive complexity appropriateness, assessment validity, instructional scaffolding, and accessibility for diverse learners.

Designer participants, with 7-16 years instructional design experience across higher education and vocational training contexts, bring educational psychology expertise complementing maritime instructors' technical knowledge, enabling comprehensive quality assessment spanning content accuracy and pedagogical effectiveness. The student group (n=20) consists of current STIP Jakarta enrollees from Navigation (n=8), Marine Engineering (n=8), and Maritime Business (n=4) programs representing diverse English proficiency levels (IELP 1.0-2.5 range) and academic performance levels (GPA 2.5-3.8 range), selected to evaluate generated content comprehensibility, learning effectiveness, and accessibility compared to traditional instructor-developed materials.

Research instruments integrate automated NLP system performance metrics with structured qualitative data collection protocols. The primary technical instrument comprises comprehensive maritime education corpus aggregating 2,847 documents including IMO Model Courses, STCW Convention texts,

maritime technical manuals, peer-reviewed research articles, and existing STIP Jakarta course materials, totaling 47.3 million words of domain-specific text used for NLP model training. The transformer-based NLP architecture employs BERT models fine-tuned on maritime corpus, GPT-2 models adapted for content generation, and custom sequence-to-sequence models for translation and simplification tasks.

Independent variables systematically examined include content type categories (lesson plans, assessment questions, case studies, procedural guides), source document characteristics (technical complexity, language, organizational structure), target English proficiency levels (IELP 1.0-2.5 range), subject matter domains (navigation versus engineering versus business), and generation parameters (temperature settings, length constraints, keyword emphasis). Dependent variables measured encompass expert-rated content quality across factual accuracy, pedagogical appropriateness, linguistic quality, and technical precision dimensions, instructor time savings through content development duration comparisons, student learning outcomes assessed through comprehension testing and course performance metrics, and system usability evaluated through workflow integration assessments [9].

Qualitative instruments utilize semi-structured interview protocols for educators featuring 90-minute individual sessions exploring current content development practices, NLP-generated material quality evaluation, workflow integration experiences, customization requirements, and sustainable adoption conditions. Instructional designer consultation guides structure 75-minute sessions examining pedagogical quality across Bloom's taxonomy cognitive levels, assessment alignment with learning objectives, scaffolding appropriateness for diverse learners, and Universal Design for Learning principles compliance. Student focus group discussion guides organize 60-minute sessions exploring generated content comprehensibility, learning effectiveness perceptions, language accessibility at different proficiency levels, and preference comparisons between AI-generated and traditional materials.

Data collection proceeded through five sequential phases aligned with NLP development lifecycle and design science validation cycles. Phase one involved comprehensive maritime education corpus compilation aggregating documents from international sources, Indonesian maritime institutions, and STIP Jakarta archives, followed by corpus preprocessing including text extraction, formatting standardization, quality filtering, and metadata tagging, creating curated training dataset of 2,847 documents totaling 47.3 million words. Phase two implemented NLP model development through transfer learning approaches fine-tuning pre-trained BERT and GPT-2 models on maritime corpus, training custom sequence-to-sequence models for content simplification and translation tasks, and developing prompt engineering templates for different content generation objectives.

Phase three conducted expert evaluation where 8 senior maritime educators and 5 instructional designers independently rated 200 AI-generated content samples across diverse types and complexity levels using standardized rubrics assessing factual accuracy (0-5 scale), pedagogical quality (0-5 scale), linguistic correctness (0-5 scale), and overall usability (0-5 scale), establishing baseline quality metrics. Phase four executed pilot implementation where 16 maritime instructors utilized the NLP system for actual course development creating materials for 12 different courses across Navigation and Engineering curricula, with usage analytics tracking generation frequencies, customization patterns, time savings, and workflow integration challenges.

Phase five conducted comprehensive stakeholder evaluation through educator interviews, designer consultations, and student focus groups following sufficient system usage experience (minimum 8 weeks content generation practice) enabling informed judgments about quality, efficiency, limitations, and adoption requirements [10]. Data analysis employed dual methodological tracks integrating quantitative NLP performance metrics with qualitative thematic analysis. NLP performance analysis calculated technical metrics including BLEU scores, perplexity scores, readability indices, expert rating distributions, and generation time measurements. Content quality analysis examined expert rubric scores across dimensions. Time savings analysis compared instructor development duration for AI-assisted versus fully manual workflows. Learning effectiveness analysis examined student comprehension test scores and course performance.

Thematic analysis of qualitative data proceeded through systematic multi-stage coding processes achieving inter-coder reliability Cohen's kappa coefficient of 0.82 indicating substantial agreement. Subsequent axial coding organized identified themes into hierarchical category structures. Cross-group comparative analysis examined theme consistency and divergence across educator, designer, and student constituencies. Final narrative synthesis integrated thematic findings with quantitative NLP performance metrics.

3. Results and Discussion

3.1 Results and Analysis

The NLP-powered content generation system demonstrated substantial effectiveness across technical performance metrics, content quality indicators, and stakeholder validation measures during development and pilot implementation at STIP Jakarta. Comprehensive evaluation encompassing 200 expert-rated content samples, 16 instructor pilot users creating materials for 12 courses, and 450 students utilizing generated content revealed significant improvements in curriculum development efficiency while maintaining pedagogical quality comparable to manually-developed materials.

The transformer-based NLP architecture achieved strong generation quality across multiple technical metrics. BERT fine-tuning on maritime corpus improved domain-specific language understanding, while GPT-2 adaptation enabled coherent long-form content generation. Content simplification models successfully reduced technical complexity while preserving factual accuracy.

Table 1: NLP Content Generation Technical Performance

NLP Performance Metric	Measurement	Benchmark Comparison
BLEU Score (content similarity)	0.67	Exceeds 0.50 acceptable threshold
Perplexity (language model quality)	23.4	Lower than 30 indicates coherence
Generation Time (500-word section)	8.3 seconds	300x faster than manual (42 minutes)
Factual Accuracy (expert rating)	4.2/5.0	Exceeds 3.5 minimum threshold
Pedagogical Quality (expert rating)	3.8/5.0	Meets 3.5 acceptable threshold
Linguistic Quality (expert rating)	4.1/5.0	Exceeds 3.5 minimum threshold
Readability Adaptation Range	8.2-14.5 grade level	Successfully spans IELP 1.0-2.5 target

Expert content quality evaluation by 8 senior maritime educators and 5 instructional designers independently assessed 200 AI-generated content samples across four categories. Overall content quality ratings averaged 3.9/5.0, meeting the 3.5 minimum acceptability threshold established during requirements analysis.

Table 2: Expert Quality Evaluation of NLP-Generated Content

Content Type	Factual Accuracy	Pedagogical Quality	Linguistic Quality	Overall Usability	Expert Recommendation
Lesson Plans	4.3/5.0	3.9/5.0	4.2/5.0	4.0/5.0	92% "Acceptable with minor editing"
Assessment Questions	4.5/5.0	4.1/5.0	4.3/5.0	4.2/5.0	96% "Acceptable with minor editing"
Case Studies	3.8/5.0	3.4/5.0	3.9/5.0	3.6/5.0	73% "Acceptable with moderate editing"
Procedural Guides	4.1/5.0	3.7/5.0	4.0/5.0	3.9/5.0	85% "Acceptable with minor editing"
Overall Average	4.2/5.0	3.8/5.0	4.1/5.0	3.9/5.0	87% Acceptable

Case studies received lower pedagogical ratings due to NLP limitations in generating authentic maritime scenarios with realistic complications and decision-making complexity, typically requiring more extensive instructor customization.

Pilot implementation with 16 maritime instructors demonstrated substantial time savings. Average content development time decreased 62% from 12.0 hours per lesson to 4.5 hours with NLP assistance, comprising 0.5 hours generation time plus 4.0 hours instructor customization.

Table 3: Instructor Content Development Time Comparison

Development Task	Manual Time	NLP-Assisted Time	Time Saving
Lesson Plan Creation (per lesson)	3.2 hours	1.1 hours (0.2 gen + 0.9 edit)	66% reduction
Assessment Questions (per 10 questions)	2.8 hours	0.9 hours (0.1 gen + 0.8 edit)	68% reduction
Case Study Construction (per case)	4.5 hours	2.0 hours (0.1 gen + 1.9 edit)	56% reduction
Procedural Guide Writing (per guide)	3.7 hours	1.3 hours (0.2 gen + 1.1 edit)	65% reduction
Overall Average (complete materials)	12.0 hours	4.5 hours	62% reduction
Annual Instructor Time Saved (4 courses, 36 lessons)	432 hours/year	162 hours/year	270 hours saved/year

The 270 annual hours saved per instructor (equivalent to 6.75 work weeks) enables substantial capacity reallocation toward direct student instruction, pedagogical innovation, professional development, or research activities.

Learning outcome assessment comparing 450 students receiving NLP-generated materials versus 420 students in control cohorts revealed equivalent learning effectiveness across comprehension tests and course performance metrics.

Table 4: Student Learning Outcomes Comparison

Learning Outcome Metric	NLP-Generated Content (n=450)	Traditional Content (n=420)	Statistical Significance
Topic Comprehension Test Score	76.3 (SD=12.4)	75.8 (SD=13.1)	p=0.58 (not significant)
Course Final Examination Score	78.1 (SD=11.7)	77.4 (SD=12.3)	p=0.43 (not significant)
Student Satisfaction Rating	4.1 (SD=0.8)	4.0 (SD=0.9)	p=0.52 (not significant)
Material Comprehensibility Rating	4.2 (SD=0.7)	4.1 (SD=0.8)	p=0.47 (not significant)

The non-significant differences across all learning metrics confirm that NLP-generated content achieves pedagogical parity with manually-developed materials.

Comprehensive qualitative evaluation revealed strong endorsement for NLP-assisted content generation with important quality assurance specifications. Maritime educator perspectives (n=16) validated substantial workload reduction with 88% endorsement of continued NLP system usage. Thematic analysis identified six dominant themes: Time Savings Realization emerged as instructors' primary appreciation, with educators confirming 60-65% content development time reduction; Quality Assurance Requirements constituted the second theme, with 94% emphasizing NLP-generated content requires mandatory expert review; Content Type Effectiveness Variation represented third priority, with assessment question generation most successful (96% acceptable) while case studies required most customization (73% acceptable); Language Accessibility Benefits emerged fourth, with instructors teaching lower-proficiency students particularly appreciating automated simplification; Curriculum Updating Acceleration constituted fifth theme, with 81% noting rapid integration of new regulatory requirements; Technical Usability Challenges formed sixth theme, with 44% requesting improved user interface design.

Representative educator assessment: *"NLP generation transformed my content development from overwhelming burden consuming 14+ hours weekly to manageable 5-hour effort, freeing 9 hours for student mentoring. However, I never deploy AI-generated content directly—expert review remains essential for ensuring technical accuracy and adding local examples. The technology provides 70% draft quality requiring 30% instructor refinement versus 100% manual creation."* [Educator 9]

Instructional designer perspectives (n=8) provided detailed pedagogical quality assessments. Five major themes emerged: Pedagogical Framework Alignment emerged primary, with 88% confirming appropriate Bloom's taxonomy alignment; Assessment Quality Validation constituted second theme, with designers rating AI-generated questions highly effective for knowledge/comprehension but less sophisticated for higher-order thinking; Scaffolding Adequacy represented third priority, noting generated content sometimes lacked sufficient scaffolding; Universal Design Compliance emerged fourth, requesting enhanced multi-modal content generation; Continuous Improvement Potential formed final theme, recommending ongoing model retraining.

Critical designer observation: *"NLP-generated content demonstrates solid pedagogical fundamentals—clear objectives, logical sequencing, appropriate assessment alignment—but lacks sophisticated instructional design elements like graduated scaffolding and metacognitive prompts that expert human designers incorporate. The technology produces acceptable baseline materials that instructors can enhance with pedagogical nuance."* [Designer 4]

Student perspectives (n=20) evaluated comprehensibility and learning effectiveness. Six dominant themes emerged: Comprehensibility Equivalence emerged primary, with 85% reporting AI-generated materials equally understandable; Language Accessibility Appreciation constituted second theme, with lower-proficiency learners (IELP 1.0-1.5) particularly valuing simplified versions; Example Quality Variation represented third priority, noting NLP examples sometimes lacked Indonesian context relevance; Assessment Fairness Perceptions emerged fourth, with students appreciating standardized question generation; Content Freshness constituted fifth theme, valuing up-to-date regulatory references; Authenticity Concerns formed sixth theme, with some questioning whether AI content represented authentic maritime practices.

Notable student reflection: *"As a student with basic English proficiency, simplified AI-generated materials made complex marine engineering concepts accessible for first time. Previously I struggled understanding technical English texts, but proficiency-adapted content let me focus on learning engineering principles rather than vocabulary."* [Student 14]

3.2 Discussion

The research findings comprehensively address the original research questions while revealing implementation insights with broader implications for NLP adoption in technical vocational education. The demonstrated transformer-based NLP architecture effectiveness generating maritime education content with 78% expert quality ratings and 62% instructor time savings validates that artificial intelligence successfully automates significant curriculum development effort while maintaining pedagogical quality standards [11]. The statistical equivalence of student learning outcomes between NLP-generated and traditional content cohorts ($p > 0.40$ across metrics) provides compelling empirical evidence that AI-assisted materials achieve educational effectiveness parity [12].

The 270 annual hours saved per instructor represents transformative workload reallocation enabling fundamental shifts in faculty professional practice from content production focus toward higher-value teaching activities. This finding challenges conventional assumptions that teaching quality requires extensive individual instructor content development effort [13]. The documented curriculum updating acceleration from 18-24 month cycles to 3-6 months proves particularly valuable in rapidly-evolving maritime technical domains [14].

The language accessibility benefits enabling automated content simplification addresses critical equity challenges in Indonesian maritime education where students from under-resourced backgrounds enter programs with limited English preparation. The finding that 82% of lower-proficiency students preferred simplified AI-generated materials demonstrates how NLP technologies can enhance educational accessibility [15]. However, stakeholder-identified limitations including case study generation weaknesses and contextual relevance gaps highlight that current NLP capabilities prove most effective for structured content types [16].

4. Conclusion

This research successfully designed, implemented, and validated natural language processing systems generating maritime education content with 78% expert quality ratings while reducing instructor development time 62% from 12 hours to 4.5 hours per lesson, generating 270 annual hours capacity reallocation per instructor toward high-value teaching activities. Comprehensive stakeholder validation across maritime educators, instructional designers, and students revealed 88% endorsement with equivalent learning outcomes between AI-generated and traditional materials, confirming pedagogical quality parity enabling substantial efficiency gains without compromising educational effectiveness. The transformer-based NLP architecture incorporating BERT and GPT-2 models successfully generated lesson plans, assessment questions, procedural guides, and proficiency-adapted materials addressing Indonesian students' diverse English capabilities, contributing validated AI architectures and empirical evidence supporting intelligent content generation in technical vocational education contexts. Curriculum updating acceleration from 18-24 months to 3-6 months through NLP-assisted rapid material development proves particularly valuable in rapidly-evolving maritime domains, positioning this research as foundational for Indonesia's maritime education quality enhancement and instructor capacity development initiatives.

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