（ 続紙 1 ）

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論文題目	A Personalized Formative Assessment System for E-book Learning (電子書籍を用いた学習のための個別化された形成評価支援システム)		

（論文内容の要旨）

Assessment is a common approach for evaluating students' comprehension and retention after learning knowledge. In contrast to summative assessment (such as quizzes or exams) that focuses on one-time evaluation, formative assessment aims to improve student learning through repeated practice, receiving feedback, and adjusting behavior. However, several challenges may occur when employing formative assessment activities in real-world settings. First, generating additional questions for formative assessment can burden teachers due to time and resource constraints. Students may also demonstrate various behaviors during the formative assessment due to a lack of teacher surveillance. Unusual and nonstandard behaviors can affect the success of formative assessment. Second, student engagement with the assessment may be reduced due to a lack of background knowledge, extremely difficult questions, or time management. Therefore, a system that helps teachers generate questions, identify students' patterns of formative assessment behavior, and motivate students to participate actively in practice is essential. While existing studies have proposed advanced techniques for question generation and achieved promising results, most studies were conducted in laboratory settings or using standard datasets for performance competitions. The educational value of question generation remains to be further investigated as most approaches did not concern with the sentence selection process but mainly with converting a given sentence or paragraph into a question. In addition, although previous studies have identified several effective and nonstandard behaviors, most only considered basic features such as the frequency of attending practice, and the relationship between nonstandard behaviors and learning performance is lacking. Finally, most existing CAT (computerized adaptive testing) methods were designed for accurate knowledge assessment rather than for learning, making it challenging to develop formative assessment systems.

This research aims to address these challenges by applying text summarization, question generation, CAT, and learning memory cycle models to propose a system that can automatically generate questions and recommend questions. Several experiments were conducted to examine the effectiveness of the proposed system in the e-book learning contexts. Meanwhile,

clustering analysis was employed to analyze students' formative assessment behaviors of using the proposed system, and its influence on learning performance was explored. The system involved four processes: sentence selection, question generation, assessment behavioral analysis, and question recommendation. This thesis first compared three text summarization models for key sentence selection and examined whether the selected sentences could be used to score students' text marking skills, which is an essential reading skill. Then, a formative assessment system was proposed for students to practice their learned knowledge. This thesis also applied TextRank to select keywords for the selected sentences for generating fill-in-the-blank questions. Next, this research employed hierarchical clustering to analyze students' formative assessment behaviors while using the system and identified behaviors that influenced learning performance. Finally, to create personalized formative assessment, the system integrated a CAT approach and a learning memory cycle model to recommend questions based on students' retention of information learned from each item.

In this thesis, the effectiveness of each process in promoting e-book learning was evaluated through four experiments. Participants in all experiments learned the materials on an e-book reading system, BookRoll. This research measured whether students' reading skills, engagement and comprehension could be enhanced by taking machine-generated formative assessment. Students' patterns of formative assessment behaviors were explored, and their relationship to learning performance was investigated. In addition, the study examined whether the adaptive feature of the assessment system could increase students' learning engagement and performance. The results showed that students' reading skills, engagement, and comprehension improved significantly after repeatedly taking the generated formative assessment than those who restudied the materials. In addition, the effectiveness of the assessment was more pronounced when students actively participated in the practice tests and did not exhibit nonstandard behaviors during the assessment process. The evaluation of the proposed adaptive assessment system showed that the recommendation based on CAT and the learning memory cycle model were more effective than the recommendation based on CAT alone in improving students' engagement in assessment and their learning performance.

（続紙 ２ ）

（論文審査の結果の要旨）

形成的評価(Formative assessment)は、生徒が反復練習を使って学習するのを支援する学習活動である。 近年のテクノロジーとデジタル学習の発展により、形成的評価は教師が実施しやすくなっている。そこで本研究では、質問を自動的に生成し、生徒の行動を検出し、質問を推奨できる個別化された形成的評価システムを開発した。具体的には、本研究では、以下の２つの観点から研究を行い、研究成果を得た。

1. まず、ほとんどの既存の問題生成手法は、テキストを問題に変換することに重点を置いているが、学習教材用の教育的な質問を生成する場合、質問生成モデルは最初にどの文が質問する価値があるかを特定する必要がある。 したがって、この研究ではBERTを適用して質問に値する文を選択し、TextRankを使用して穴埋め質問を生成した。 形成的評価システムが開発され、実際の教育環境で評価される。 その結果として、生徒が機械で生成された質問を練習することで、読書への取り組みと学習パフォーマンスを向上させることができることを示している。
2. 次に、生徒の行動が形成的評価の成功に影響を与える可能性がある。この研究では、提案された形成的評価システムを使用する生徒の行動を調査し、学習パフォーマンスへの影響を調べる。それにより、形成的評価の成功には積極的な参加が不可欠であることがわかる。 さらに、生徒は、詰め込み、推測、ヒントの乱用などの非標準的な行動を示す場合がある。 これらの行動は、形成的評価の効果を低下させ、学習パフォーマンスの低下につながる。
3. 最後に、生徒の個人情報に基づいて質問を推奨することで、形成的評価への生徒の関わりを強化できる。 この研究では、各質問に対する学生の記憶保持を考慮することにより、既存のコンピューター化された適応テスト（Computerized adaptive testing）アプローチを改善する。 この結果は、生徒がまだ慣れていない、または忘れている可能性のある質問を推奨することで、形成的評価と読書への生徒の関与を高め、学業成績の向上につながることを示唆している。

以上のように、本研究は、教師が質問を生成し、さまざまな形成的評価行動を特定し、質問を推奨するのに役立つ、個別化された形成的評価システムを提案している。 その結果は、個別化された学習ツールの開発と評価に貢献するものである。

よって、本論文は博士（情報学）の学位論文として価値あるものと認める。また、令和５年２月２４日、論文内容とそれに関連した事項について試問を行った結果、合格と認めた。なお、本論文は、京都大学学位規程第１４条第２項に該当するものと判断し、公表に際しては、当面の間当該論文の全文に代えてその内容を要約したものとすることを認める。

要旨公開可能日：２０２３ 年 ６ 月 ２３ 日以降