（ 続紙 1 ）

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論文題目	GLOBE: Data-Driven Support for Group Learning （GLOBE: データ駆動型グループ学習支援システム）		

（論文内容の要旨）

Collaborative learning has become increasingly popular in various educational contexts, benefiting the development of soft skills such as critical thinking, problem-solving, and interpersonal communication, which are highly valued in modern society. With the introduction of tablets into classrooms by the GIGA school project in Japan, computer-supported collaborative learning (CSCL) and learning analytics (LA) can provide digital tools and data support, creating immense opportunities to enhance these activities with information technologies.

However, obstacles to providing a valid scaffold for group learning still exist. In terms of group formation, teachers tend to resort to random grouping or just pairing neighboring students owing to difficulties to do it in a real-time manner. Students of traditional classrooms seldom use digital tools for group learning, which leads to a cold start problem for the lack of enough learning logs to create learner models that can be used to allocate students based on their attributes. Even with the support of computers, there remains a chance that teachers would get overwhelmed if they are not familiar with the computer-supported tools for orchestration. In addition, to evaluate the performance of the group work, only the teacher's evaluation is not enough since one teacher cannot check what is happening for all groups during group learning. Currently, many researchers focus on utilizing LA tools during the orchestration phase of one group work, while valid support for group formation and evaluation phases deserves further attention.

To address these issues, this research proposed the Group Learning Orchestration Based on Evidence (GLOBE) framework, which supports group learning in various contexts using data-driven systems. The aim was to apply LA to the CSCL process, consolidating various learning log data to support each phase of group activities and figure out predictors of successful group work from these inputs. The research introduced two key innovations: (1) the utilization of multiple data sources for group formation through genetic algorithms, and (2) the implementation of learning analytics for optimized parameter selection and purpose-based recommendations to teachers by employing evidence of continuous multiple group learning activities.

The implementation of the GLOBE framework took three steps: synthesizing data, utilizing data, and analyzing data. Firstly, a group formation system using genetic algorithms was designed and implemented to form groups using learning log data from various sources. Annotation data of common markers could also be reflected in group formation. Secondly, a continuous data-driven support paradigm for the entire group learning process was proposed, incorporating input from peer and teacher evaluations for subsequent groupings. Although only a few student model data

were used in the current studies, further opportunities for LA-enhanced group work orchestration were revealed the continuous data flow, even in classroom-based contexts where no initial data existed. Furthermore, by utilizing accumulated group learning evidence in the GLOBE ecosystem, predictive group formation indicators were explored that can enable automatic group formation based on teachers' objectives in different contexts for desirable performance in subsequent group learning activities.

This doctoral dissertation introduced the group formation and peer evaluation modules in the GLOBE framework and the continuous data flow, with four empirical studies corresponding to the three data-driven steps of GLOBE implementation. The empirical studies in K12 schools and a university showed that the GLOBE framework provides a low threshold for teachers to adapt the data-driven workflow for group learning design, promoting the use of digital systems in routine practice. Implementations of GLOBE systems showed that they could reduce the time for teachers and students from trivial works of group formation and evaluation. Additionally, a new perspective was suggested to explore how group composition with diverse student model data tends to make a difference in the performance of subsequent phases. By investigating specific student model variables for group formation, heterogeneity could be inspected among which characteristics weigh more to affect the subsequent group learning process and outcome.

（続紙 ２ ）

（論文審査の結果の要旨）

グループ学習は、現代社会において批判的思考、問題解決能力、コミュニケーション力などの非認知スキルの習得に貢献する。本研究では、データ駆動でグループ学習を支援するシステムを開発し、グループ学習活動を調査・分析した。具体的には、以下の２つの観点から研究を行い、次のような成果を得た。

まず、従来のグループ編成の研究のほとんどは、成績データに基づいてグループを作成しており、様々な学習活動のログデータを用いることはほとんど行われてこなかった。しかし、本研究では、複数のデータソースを利用して遺伝的アルゴリズム（GA）を用いてグループ編成を行う手法を提案した。これにより、成績データに基づく従来のグループ形成の制約を克服した。具体的には、本研究で開発された GLOBE システムでは、小テストなどの成績などのスコアデータに加えて、読書中のページ遷移やマーカー等の閲覧行動データや過去のグループ学習の評価結果等を組み込み、多種多様な数値指標を考慮してグループ編成を行うことを可能にした。実証実験により、GLOBE システムは、教師の想定外のグループの構成員の組み合わせを提案し、教師のグループ編成におけるバイアスを軽減するだけでなく、グループ編成にかかる時間を減らすことができることを確認した。

また、従来の研究は、単一のグループ学習のためのグループ編成のみを対象としていたが、本研究では、複数回にわたるグループ学習の活動データを活用して、グループ学習の目的に基づいてグループ編成のためのパラメータ選択の最適化を行う手法を提案した。これにより、グループ学習の目的に応じて、グループ編成のためのパラメータ設定が自動化され、効果的なグループ学習を可能とすることを実験により確かめた。

以上をまとめると、この研究は学習データの収集と分析技術の活用により、データ駆動型のグループ学習支援システムの構築に関する理論的な研究と実践的な成果をまとめたものであり、学術的な理解や実践的な応用に寄与するものである。

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８月２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、本論文のインターネットでの全文公表についても支障がないことを確認した。

要旨公開可能日： 令和５ 年 １０月 １日以降