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研究課題名（和文）Research and Development of a Novel Learning Support Environment on Synchronized Multiple Devices with Affordance

研究課題名（英文）Research and Development of a Novel Learning Support Environment on Synchronized Multiple Devices with Affordance

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研究成果の概要（和文）：コロナ禍により、方向性の調整が起こったが、本プロジェクトは様々な側面での貢献できた。最初に提案したマルチデバイス学習環境（MDLE）は、個人の学習支援を想定した。デジタル教科書の閲覧パスを視覚化する学習ダッシュボード、閲覧行動と学習効果の分析、インタラクティブなコース推薦UIなど、補足情報を提供できた。その後、MDLEは屋内・屋外の協調学習環境に拡張された。博物館向け屋内ARナビゲーションや地図ストーリーテリングツールが、教育向けに開発された。最後に、本研究は従来の学習設定を打破する可能性を探求し、地域教育における協調学習のためのMDLEに焦点を当たって、後続の研究（基盤C）を啓発した。

研究成果の学術的意義や社会的意義

学生手持ちの複数の端末の連携により、各端末の長所を發揮できる新たな学習支援環境の形成を目指して、プロトタイプを試行的に研究開発した。デジタル教科書の閲覧パスなど、新たな学習用データ分析ツールの開発は、学習者の理解とエンゲージメントを高めるための新たな手法を模索し、デジタル時代の学習体験の改善の可能性を示した。屋内・屋外協調作業を支援するプラットフォームの提案と開発は、教育の可能性を広げ、地域社会の教育資源を最大限に活用し、多世代間のコミュニケーションと学習を促進する新たな道筋を提供した。

研究成果の概要（英文）：Although the shift of the COVID-19 situation has changed the research environment and direction of this project, it has achieved contributions in different aspects. Initially, the proposed multi-device learning environment (MDLE) was expected to support classroom study for a single student. MDLE provides supplementary information including a learning dashboard visualizing the reading path on digital textbooks, an analysis of reading behaviors and their connections with learning performances, and an interactive course recommendation interface. MDLE is then extended to indoor & outdoor collaborative learning settings. Indoor AR navigation for a museum and illustrative map storytelling tools are developed on mobile devices for educational purposes. Finally, this research sought to break through the conventional learning settings with contemporary devices and inspired the follow-up research applying MDLE in collaborative regional education, which is accepted as a Kiban-C project.

研究分野：学習支援システム，空間情報科学

キーワード：learning support mobile learning multiple devices learning dashboard learning analytics human-centered design collaborative learning cross-platform

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## 1. 研究開始当初の背景

Schools and universities have widely applied Learning Support Environments, as they can benefit teachers and students with functionality and convenience. Furthermore, learning analytics of the large-scale educational data obtained from such environments brings opportunities for reflections on teaching and learning strategies. Many secondary developments based on the existing learning environments provide students with valuable tools. Based on the learning log data of its digital textbook system, the applicant was studying and developing a dashboard with visualized learning processes and behaviors supporting metacognition for self-regulated learning.

Young students are considered quick learners of ICT tools, but their requirements and preference in learning environments should be addressed. The existing learning support environment still has usability issues, according to our questionnaire-based investigations of the students. Especially the students have to switch between the views of different functions, which may interrupt the use of the primary teaching materials. Such problems can prevent the students from using the advanced tools supporting their learning. On the other hand, many young students are more familiar with mobile devices, such as smartphones, than conventional computers. However, the mobile version of the learning support systems are usually duplications of their PC versions with layouts adapted to smaller screens. The students' devices and their skills still need to be fully utilized.

The motivation of this research was to explore how can the learning support environment facilitate the learners with all kinds of devices they have and are familiar with together to utilize their advantages to reduce the students' working loads and provide more useful supplementary information in a user-centered manner. In addition, this research was expected to evaluate the effectiveness of such a multi-device learning environment in different learning scenarios.

## 2. 研究の目的

This research aimed to study, design and develop a novel learning support environment with multiple synchronized devices (typically, the student's PC, tablets, and smartphone), facilitating learners with less working load and more useful supplementary information. More specifically, this research was expected to

(1) Develop a cross-platform and adaptive framework to realize the multi-device learning support environment with different combinations of devices of different sizes and platforms.

(2) Implement a prototype of the environment based on the framework and evaluate its adaptivity and effectiveness in different learning scenarios through practical experiments.

## 3. 研究の方法

A novel learning support environment with multiple synchronized devices of different types and sizes was studied to utilize their advantages to realize more efficient learning in different scenarios. Prototypes were developed based on studies of an affordable technological framework and collaborative designs with students and teachers. Its feasibility and effectiveness were evaluated with experiments.

The first step was the concept design of the multi-device user interfaces with Fast, agile development of small-scale prototypes with combinations of functions from the existing learning support systems of the university deployed on different devices; and Collaborative design with students, teachers, and developers by interviews and focus

groups based on the formative evaluations of the fast prototypes. This step figured out preferred combinations of devices in different learning scenarios and the contents and functions of each device.

The second step was the study of the technological framework for the adaptive multi-device environment, which made clear the important technological issues that need to be solved in developing the initial prototype to a cross-platform, scalable, and adaptive solution for practical uses, for example, Synchronizing the user's operations and contents on different hardware and software platforms; Robustness of the multi-device synchronizing in different network conditions; Adaptiveness of the system to different combinations of screen sizes and operation types.

The third step was the development of practical prototypes and formative evaluations by experiments. The practical prototype was designed to be used in two main learning scenarios: personal study and group study. In personal study scenarios, such as classroom or self-study, the prototype sought to provide supplementary information aside from the main learning material with a secondary screen. In the group study scenarios, the prototype sought to provide a collaborative platform for tasks using different types of devices.

#### 4 . 研究成果

The COVID-19 situation has dramatically changed the research environment of this project, as the anticipated use cases of the proposed multi-device learning environment (MDLE) were lectures in classrooms. As the lectures all switched to online forms in May 2020, it also brought opportunities to rethink the potential of MDLE in the new normal. Questionnaires to the students taking online courses are conducted to collect their usage of existing ICT devices at home. Instead of looking at the screen or blackboard of the teacher while operating their own computers in a classroom, the students attending the online lectures have to frequently switch between the online meeting software, web browsers, and other tools. Some students use their smartphones or tablets as secondary screens to reduce their workload. It has shown the potential of MDLE in online or self-learning scenarios.

For the students to better understand their learning activities and reflect on future learning strategies, a learning dashboard visualizing the analytics from the operation logs of the students' online learning activities was proposed, and a prototype visualizing the reading paths on digital textbooks was developed. The reading behaviors in viewing digital textbooks were visualized and analyzed to figure out the relations between the student's learning styles and reading patterns and the connections to their performances. The results were presented at international conferences, with one of them receiving an award, and then published as a book chapter. Such learning dashboard tools served as a component in MDLE to provide supplementary information aside from the screen of the main learning material.

To support the students in a larger scope than a course, an interactive user interface for course recommendations in university environments was designed based on an investigation of course choice motivations. The visualizations of courses' categories, types, and relations on an interactive web UI based on different criteria were realized and evaluated. The visualization techniques were also applied in the further development of MDLE. The results were presented at international and domestic conferences, and three journal papers were published.

As the study progressed, the difficulty of proposing a one-fit-all solution of MDLE in such small-scale research was revealed. The research adjusted the goal to a more specific and concrete application scenario of MDLE for prototype development, which was groupwork-based practice courses with indoor and outdoor activities. In such a scenario, the needs for mobile devices and multi-device synchronization are more explicit than classroom learning. A prototype focusing on multi-device and multi-user collaboration was conceived. The project developed fundamental components for an MDLE prototype supporting indoor and outdoor group work to create georeferenced hand-drawn map content, which included a server-side Python package and a client-side JavaScript

module dealing with data structures and geometric calculations. Development of an indoor AR navigation app for a museum and illustrative map storytelling tools on mobile devices were also attempted for educational purposes. Three papers were published in this research aspect.

Finally, this research explored the possibility of breaking through the conventional learning settings with contemporary devices. It inspired the follow-up research focusing on applying MDLE in collaborative regional education, which is accepted as a Kiban-C project, "Research on a Learning Environment based on Synchronized Heterogeneous Devices for Collaborative Learning between Young Students and Seniors in Regional Education" (23K11362).

## 5. 主な発表論文等

〔雑誌論文〕 計5件（うち査読付論文 5件/うち国際共著 0件/うちオープンアクセス 3件）

1. 著者名 Ma Boxuan, Lu Min, Taniguchi Yuta, Konomi Shin'ichi	4. 巻 9
2. 論文標題 Exploring jump back behavior patterns and reasons in e-book system	5. 発行年 2022年
3. 雑誌名 Smart Learning Environments	6. 最初と最後の頁 2:1~2:23
掲載論文のDOI（デジタルオブジェクト識別子） 10.1186/s40561-021-00183-6	査読の有無 有
オープンアクセス オープンアクセスとしている（また、その予定である）	国際共著 -
1. 著者名 Ma Boxuan, Lu Min, Taniguchi Yuta, Konomi Shin'ichi	4. 巻 16
2. 論文標題 CourseQ: the impact of visual and interactive course recommendation in university environments	5. 発行年 2021年
3. 雑誌名 Research and Practice in Technology Enhanced Learning	6. 最初と最後の頁 1:1~1:24
掲載論文のDOI（デジタルオブジェクト識別子） 10.1186/s41039-021-00167-7	査読の有無 有
オープンアクセス オープンアクセスとしている（また、その予定である）	国際共著 -
1. 著者名 Ma Boxuan, Lu Min, Taniguchi Yuta, Konomi Shin'ichi	4. 巻 8
2. 論文標題 Investigating course choice motivations in university environments	5. 発行年 2021年
3. 雑誌名 Smart Learning Environments	6. 最初と最後の頁 31:1~31:18
掲載論文のDOI（デジタルオブジェクト識別子） 10.1186/s40561-021-00177-4	査読の有無 有
オープンアクセス オープンアクセスとしている（また、その予定である）	国際共著 -
1. 著者名 Chen Li, Lu Min, Goda Yoshiko, Shimada Atsushi, Yamada Masanori	4. 巻 1
2. 論文標題 Learning Analytics Dashboard Supporting Metacognition	5. 発行年 2021年
3. 雑誌名 Balancing the Tension between Digital Technologies and Learning Sciences	6. 最初と最後の頁 129 ~ 149
掲載論文のDOI（デジタルオブジェクト識別子） 10.1007/978-3-030-65657-7_8	査読の有無 有
オープンアクセス オープンアクセスではない、又はオープンアクセスが困難	国際共著 -

1. 著者名 有川 正俊、大場 康平、伊東 慎平、佐藤 諒、ルウ ミン	4. 巻 63
2. 論文標題 インドARナビゲーション実現のための基本フレームワークの提案と実証実験	5. 発行年 2022年
3. 雑誌名 情報処理学会論文誌	6. 最初と最後の頁 1821 ~ 1829
掲載論文のDOI (デジタルオブジェクト識別子) 10.20729/00222736	査読の有無 有
オープンアクセス オープンアクセスではない、又はオープンアクセスが困難	国際共著 -

[学会発表] 計6件(うち招待講演 0件/うち国際学会 4件)

1. 発表者名 Boxuan Ma, Min Lu, Yuta Taniguchi, Shin'ichi Konomi
2. 発表標題 Exploration and Explanation: An Interactive Course Recommendation System for University Environments
3. 学会等名 Fourth Workshop on Exploratory Search and Interactive Data Analytics (ESIDA), co-located with 26th ACM Conference on Intelligent User Interfaces (ACM IUI 2021) (国際学会)
4. 発表年 2021年

1. 発表者名 Boxuan Ma, Min Lu, Shin'ichi Konomi
2. 発表標題 Understanding Student Slide Reading Patterns During the Pandemic
3. 学会等名 18th International Conference on Cognition and Exploratory Learning in Digital Age (CELDA 2021) (国際学会)
4. 発表年 2021年

1. 発表者名 Li Chen, Min Lu, Yoshiko Goda, Atsushi Shimada, Masanori Yamada
2. 発表標題 Factors of the use of learning analytics dashboard that affect metacognition
3. 学会等名 17th International Conference on Cognition and Exploratory Learning in Digital Age, CELDA 2020 (国際学会)
4. 発表年 2020年

1. 発表者名 山田政寛, Min Lu, 陳莉, 合田美子, 島田敬士
2. 発表標題 学習者のメタ認知喚起を支援するダッシュボード"メタボード"の形成的評価
3. 学会等名 教育システム情報学会第45回全国大会
4. 発表年 2020年

1. 発表者名 Boxuan Ma, Min Lu, Yuta Taniguchi, Shinichi Konomi
2. 発表標題 Exploration and Explanation: An Interactive Course Recommendation System for University Environments
3. 学会等名 Fourth Intelligent User Interfaces (IUI) Workshop on Exploratory Search and Interactive Data Analytics (ESIDA) (国際学会)
4. 発表年 2021年

1. 発表者名 陸 恣, 王 静芸, 有川 正俊, 佐藤 諒
2. 発表標題 MediaLibを用いた初心者大学生向けのプログラミング授業の設計と実施
3. 学会等名 情報処理学会第85回全国大会
4. 発表年 2023年

〔図書〕 計0件

〔産業財産権〕

〔その他〕

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6. 研究組織

氏名 (ローマ字氏名) (研究者番号)	所属研究機関・部局・職 (機関番号)	備考

7. 科研費を使用して開催した国際研究集会

〔国際研究集会〕 計0件

8 . 本研究に関連して実施した国際共同研究の実施状況

共同研究相手国	相手方研究機関
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