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Developing a Digital Textbook for Statistical Analysis: Enhancing Data Science Education with Visualization and Open Data

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Abstract

Data-driven decision-making is increasingly expected in many professions; however, many university students—especially those in non-STEM disciplines—experience anxiety about statistics and mathematics. Introductory courses also tend to focus on procedural calculations, which can leave a gap between understanding statistical concepts and practical application. This practice-based case study of developing a digital textbook, Statistical Analysis, is designed to cultivate practical data utilization skills from a "zero-base" level.
The textbook helps students master an end-to-end workflow of data use, including identifying relevant data, organizing and preparing it, performing basic descriptive analysis, visualizing results, and producing evidence-based explanations. To connect learning with real-world issues, the materials incorporate Japanese public open data, such as e-Stat (government statistics) and the Regional Economy and Society Analyzing System. Excel is used for data preparation and foundational statistics, whereas Tableau—a business intelligence tool—is introduced to support interactive visualization and interpretation without requiring programming skills.
Distinctive digital features include embedded video tutorials for software operations and direct hyperlinks to data sources and practice datasets, thereby reducing technical barriers for novices. Learning activities progress from individual analysis to collaborative group work, culminating in the development of policy proposals presented using Tableau's story function. This study summarizes the design rationale, classroom implementation, and practitioner insights—underscoring what worked well, common challenges, and practical tips that may support instructors who wish to adopt similar tool-integrated, open-data-based statistics instruction.

Keywords: *Data Science Education, Digital Textbook, Open Data, Tableau, Decision-Making*

1. Introduction

In Japan, digital textbooks have been used mainly based on policy and institutional arrangements for primary and secondary education. Following the partial amendments to the School Education Act in 2018, digital materials were formally institutionalized since April 2019 as "textbook substitute materials" that may replace printed textbooks in parts of the curriculum, mainly at the primary and secondary levels. In addition, the proportion of textbooks converted into digital versions is expected to reach approximately 100% for elementary and junior high schools and about 59% for high schools by academic year 2026 [1].
In higher education, no institutional rule formally defines the use of digital textbooks, yet they are widely adopted, especially in nursing programs. One major reason is that many textbooks and reference books required for national qualifications are heavy and inconvenient to carry. Deguchi et al. [2] conducted a survey on digital textbooks with university and graduate students and found that 72% of respondents stated that they would like to try using them. The most common reason was that digital textbooks would support interactive learning. In the same survey, when asked what elements were essential for the spread of digital textbooks, approximately 82% of respondents emphasized the need for improvements in the learning environment and infrastructure. Ishida [3] implemented a university course using digital textbooks and evaluated learning effects. Students commented that "it is easy to access if you have a smartphone or tablet," "using an e-textbook helped avoid carrying bulky materials," and "sharing comments written by other students and instructors helped learning progress." At the same time, some students reported that printed textbooks were easier to use, indicating mixed opinions. In addition, Allred and Murphy [4], focusing on US university students, reported that grades were significantly and positively correlated with time spent using a digital textbook and engagement

indicators (based on MindTap logs). Thus, while the learning effects of digital textbook use have been demonstrated in some contexts, the overall adoption of digital textbooks in Japanese higher education remains limited.

The 1CORE project working group [5], operating within the 4EU+ Alliance (a consortium of major European universities), presented open-access publishing guidelines for digital textbooks in Europe. These guidelines advocate “Diamond Open Access,” a model of scholarly publishing that requires no fees from either authors or readers and aims to be fully fair and open. In this way, Europe has shown strong public efforts to develop open educational resources (OER) and open textbooks.

In the USA, publisher-driven developments have been implemented; for example, Pearson, a major publisher, announced in 2019 that 1,500 titles would be switched to a “digital-first” model [6]. In addition, within the framework of the OER movement, Rice University offers free, peer-reviewed textbooks across a wide range of fields from secondary to higher education through OpenStax [7], a nonprofit project launched at the university.

Given these trends in Japanese higher education and the growth of OER initiatives in Europe and the USA, digital textbook demands will likely increase. This situation emphasizes the need to develop textbooks that leverage distinctive features of digital media, particularly rich interactivity. In response, a digital textbook was developed for a university-level data science course, “Statistical Analysis.” This study provides a practice-based report on the developmental process and its use in classroom instruction.

2. Context and Course Setting

Shukutoku University [8] is a comprehensive university with 4 campuses, 7 faculties, and 13 departments. It promotes data science education through an institution-wide, organized approach.

“Statistical Analysis” is an elective course within S-BASIC, Shukutoku University’s university-wide foundational educational program. After a pilot implementation in the Faculty of Humanities in academic year 2023, the course was offered in the entire university from academic year 2024. Approximately 300 students, mainly second-year students, took the course. The classes are conducted in a computer lab, and students are expected to possess basic computer literacy.

The course develops students’ ability to (1) read and interpret statistical information commonly encountered in everyday life, (2) acquire fundamental knowledge and skills for efficiently organizing and summarizing data, and (3) learn visualization techniques using a business intelligence (BI) tool (Tableau).

In all 15 sessions, the curriculum is structured to build practical skills. In sessions 1–6, students learn descriptive statistics using Excel and conduct data visualization and analysis using open data sources such as e-Stat (the Japanese government’s official statistics portal) [9] and the Regional Economy and Society Analyzing System (RESAS) [10]. From session 7 onward, the course focuses on Tableau. Tableau [11] is a widely adopted data visualization tool used by large companies and local governments. It allows users to analyze data and present them visually, primarily through point-and-click interactions without requiring complex programming, making it possible to generate insights efficiently.

From session 12, the course implements problem-based learning using real-world datasets. For example, students analyze match and merchandise sales data from the soccer team VONDS Ichihara and propose possible actions based on their findings. Students also analyze results from an on-campus student survey and develop recommendations in some classes.

3. Rationale and Development Background

At Shukutoku University, a full-scale implementation of digital textbooks was introduced to the Faculty of Nursing and Nutrition in the academic year 2024, and the university has been promoting institution-wide adoption since the academic year 2025.

Regarding the rationale for adopting digital textbooks, Araki and Sugihara [12] summarize five key advantages: (1) portability and convenience, enabling learning on a single device without carrying multiple textbooks; (2) accessibility, including note-taking and highlighting functions and text-to-speech and magnification; (3) integration, allowing embedding of videos and hyperlinks in the textbook and sharing of instructors’ annotations; (4) content management, whereby updates to textbook content can be reflected for users (typically during enrollment period); and (5) the potential use of learning logs, where digital textbook log data can be analyzed in combination with other institutional teaching and

learning data. Based on these features, a digital textbook for “Statistical Analysis” was developed for use in the academic year 2025, building on existing lecture materials [13].

Existing introductory data science textbooks for university beginners are typically available as printed books or simple digital conversions of PDF files. Consequently, students expressed difficulties in following explanations of software procedures, especially for tools such as Excel and Tableau. Instructors frequently create separate PowerPoint presentations to explain procedures, which increases their workload. In addition, conventional textbooks cannot easily incorporate links to relevant data science websites, requiring students to obtain related datasets separately. Consequently, even with adequate content in existing textbooks, their usability for students remains limited. To address these issues, a digital textbook for “Statistical Analysis” was developed and adopted in the course starting in the academic year 2025.

4. Textbook Design and Learning Activities

The digital textbook “Statistical Analysis” consists of 268 full-color pages. It is published by Mirai Co., Ltd. Its editor is Toru Sugihara, and the authors are Toru Sugihara and Yoshie Matsumoto. The President’s Office of Shukutoku University supported the contract arrangements and development process. The price is 2,420 yen (2,200 yen plus tax) or approximately 15.00 EUR.

The major feature of this textbook is that it was produced only as a digital textbook, without a printed version. This design choice made it possible to fully leverage digital affordances, including embedded video materials (e.g., tutorials on how to use Tableau), hyperlinks to public resources (e.g., e-Stat), and downloadable supplementary materials, such as Excel data files and PDF handouts (available via one-click download) (Figs. 1 and 2).

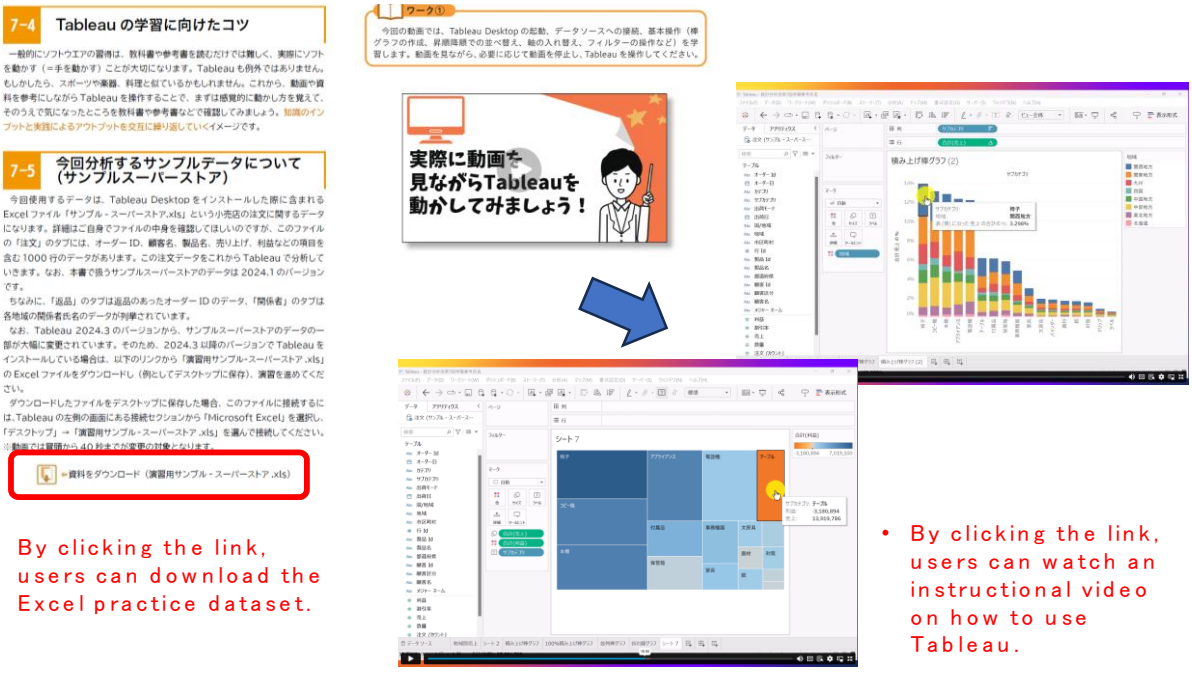

Fig. 1. Digital textbook “Statistical Analysis” (embedded Tableau tutorial videos and downloadable Excel data files).

Fig. 2. Digital textbook “Statistical Analysis” (embedded URLs to related web resources).

For the distribution platform, EDX UniText [14] provided by NTT EDX Corporation was adopted. Through this platform, instructors and students can centrally manage “Statistical Analysis” and the student handbook and other digital textbooks using either an app or a web browser. EDX UniText offers varied learning-oriented functions, such as masking tools for memorization, note-taking, full-text search, dictionary integration, external link settings, and shared annotations. It also supports linking to video and audio content. In addition, instructors can use the teacher-to-student sharing function to share their notes, highlights, and comments with students. The platform can also store learning usage logs, which can be exported as CSV files and visualized, enabling potential learning analytics, such as monitoring out-of-class learning and improving teaching based on usage patterns. Furthermore, the platform includes a digital rights management system, a technology that protects the copyright of digital content and controls or restricts its use and reproduction.
To assist students who may struggle with mathematics and numbers, the textbook provides thorough explanations, extensive use of figures and tables, and clear guidance through video materials. Having students operate tools such as Excel and Tableau allows them to conduct some form of data analysis. The textbook also emphasizes data visualization, which helps communicate analytical results more clearly. Students use Excel and Tableau, along with open data portals such as e-Stat and RESAS, to visualize data in tables and graphs. The textbook also underscores the importance of interpreting the characteristics of visualized data and articulating them in words.

The textbook is organized into four main parts:
(1) Using open data (Lessons 1–4)
(2) Descriptive statistics and visualization using Excel (Lessons 5–6)
(3) Learning basic operations of the BI tool Tableau (Lessons 7–11)
(4) Data analysis and recommendations using Tableau (Lessons 12–15)

Each lesson was designed with reference to the Backward Design framework proposed by Wiggins and McTighe [15], which involves (1) identifying desired results, (2) determining acceptable evidence, and (3) planning learning experiences and instructions.

5. Class Implementation

“Statistical Analysis” is performed in a computer lab where an instructor’s PC is installed. During class, the instructor performs operations on his/her PC and explains the relevant sections by opening the corresponding pages of the digital textbook “Statistical Analysis.” To demonstrate software such as Tableau, the instructor clicks the embedded video links and plays the content for students.
Students attend the class using desktop computers in the lab. The classroom is equipped with submonitors positioned between rows of PCs, and the instructor’s screen is projected onto these

monitors. Therefore, students can follow the textbook pages and videos displayed by the instructor on the monitors while learning. When working on in-class exercises, students may also open the digital textbook on their PCs at their seats. In addition, with relevant websites embedded in the textbook as URL links, students can access and review them immediately during class. Required datasets for analysis can also be directly downloaded from within the textbook.
The digital textbook is designed so that the class can be completed using it alone, without requiring additional materials.

6. Author Reflections and Practical Insights

6.1 What worked well

From the instructor's perspective, the elements included in the digital textbook can be evaluated and ranked based on their practical usefulness. The most important element is the set of video materials designed to support software operation procedures. In hands-on classes, instructors frequently encounter a heavy burden of repeated demonstrations. However, because the textbook embeds videos explaining concrete operations in Excel and Tableau, students can follow procedures independently at their own pace while referring to the videos. Consequently, instructors spend less time repeating the same explanations to individual students and can focus on more essential support, such as assisting students who are behind and advising on the validity of their analyses.
The next key element is accessibility to up-to-date information through external links. The textbook incorporates URL links to reference resources, enabling students to access detailed information on the internet and the latest open data immediately. This design allows instructors to efficiently direct students to relevant sources, both during class and in out-of-class learning, including information that is difficult to maintain in printed materials. In addition, because students can follow the links to trace sources and obtains additional information, the textbook more easily encourages learning behaviors, such as "checking evidence by investigating on one's own."
Searchability and reproducibility are also key practical advantages of the digital format. The digital nature of the textbook allows students to immediately search for necessary terms or procedures, thereby minimizing interruptions during instruction. Moreover, the textbook supports learning that emphasizes reproducibility—students can "look things up, follow procedures, and produce outputs"—making it easier to connect in-class and out-of-class learning.
In addition, the textbook presents a coherent sequence of learning steps that progress from "individual analysis" to "group discussion and proposal" and to "presentations." This structure enables instructors to easily design the overall course plan. By organizing learning activities in stages, data analysis is less likely to remain an isolated technical skill and more likely to be internalized as a practical process involving problem framing, decision-making, and explanation.
Finally, the availability of instructor support materials and assessment criteria (rubrics) provides a foundation for reliably implementing these activities in practice. The textbook provides instructor-only PDF materials that organize assignments and grade weights, which can substantially reduce preparation time. It also includes rubric tables for objectively evaluating group work achievement, supporting transparent grading while reducing assessment workload. Importantly, these materials are supplied as editable templates, allowing instructors to tailor their course goals and student needs, thereby balancing instructional autonomy with practical feasibility.
Although not implemented in this course, another relevant perspective is support for students who require special accommodations. One important advantage of adopting digital textbooks is their potential to reduce learning barriers for students with disabilities. For example, functions such as text-to-speech, font-size adjustment, and background-color changes can help create learning environments that better match individual needs, thereby minimizing learning barriers. Consequently, digital textbooks may substantially improve learning conditions for these students.

6.2 What was challenging

The major challenges for future work can be summarized into four points. First, infrastructure is essential: if campus foundations, such as internet connectivity, are insufficient, the use of digital textbooks can become a bottleneck in class. Second, their usability remains a concern. Compared with printed textbooks, digital materials are commonly associated with issues such as eye strain and cumbersome operations, and the user experience—covering devices, display settings, and user interfaces—should still be improved. Third, instructor workload must be addressed. Although

digitization can reduce the need for separate teaching materials, it can simultaneously increase the demands of IT-related support; therefore, careful operational design and an adequate support system are indispensable. Fourth, student learning outcomes are a key issue. Discussions regarding the effects of digital textbooks on learning outcomes can easily become impressionistic, whether in favor or against. Accordingly, continuous evaluation based on evidence—such as usage logs, learning attainment, and course evaluations—should be conducted to support evidence-based improvement and decision-making.

6.3 Development process of the teaching materials

In developing digital textbook materials, one key point to consider is the limitation of the editorial structure. At present, only a few professional editors are familiar with digital instructional materials, and implementing functions such as embedding videos, setting URL links and attaching files requires more effort than expected. Unlike conventional printed textbooks, a digital textbook cannot be completed with text alone; it must be designed and edited as an integrated set of content that includes videos, links, and supplementary files. Therefore, authors are expected not only to “write text” but also to take a perspective of “editing the entire content” and engage in integrated editorial work throughout the production process. In fact, in producing this textbook, we had a strong impression that comprehensive editing progressed in parallel with writing.

In contrast, digital textbooks offer agility that printed materials do not. In our case, a public website (RESAS) was renewed just before publication, which changed target pages and screen layouts; however, we effectively responded by quickly incorporating a PDF resource into the relevant chapter. This ease of urgent updates is a clear advantage over printed textbooks, which typically require substantial time for revision. From the perspective of classroom operation, the textbook can serve as a base for a continuous flow of explanation and video viewing, which greatly reduces the need to create and distribute separate handouts and consequently reduces instructors’ preparation workload.

Challenges also remain in sales and distribution design. Initially, we assumed only institutional sales through the NTT EDX UniText e-textbook system, and no established channel for individual purchases. After requesting individual sales, distribution through “BookLive!” and “Apple Books” became possible; however, the format we produced was not compatible with Kindle, and therefore, it could not be sold there. For wider adoption and better user convenience, it is desirable to design specifications and production procedures from the beginning with deployment across major platforms—including Kindle—in mind.

Operationally, strict management of ID registration and distribution schedules is required. For first-year students, the process from student registration to digital textbook ID issuance, textbook purchase, and system activation is tightly connected; if these procedures are not completed immediately before the semester begins, operations can easily break down. Accordingly, a careful schedule design aligned with the academic calendar is essential. In addition, instructors’ copies are sometimes delivered only shortly before the first class, which may interfere with course preparation. We have already formally requested the vendor to address unnecessary delays and plan to begin improvements on the university side from the next academic year.

7. Limitations

Regarding the limitations of this initiative, first, the quantitative evaluation of learning outcomes and operational effects on course delivery is still at the planning stage. Second, functions provided by the digital textbook are not yet fully leveraged. For example, practices such as visualizing learning behaviors through the collection and analysis of usage logs and optimizing instructional design by combining search, links, and videos remain limited in implementation. Third, some constraints are also observed in the usage environment, particularly device and platform dependence. In practice, while this textbook can be distributed through “BookLive!” and “Apple Books,” it cannot be used on platforms such as Kindle. Thus, accessibility may vary depending on users’ devices and service environments.

8. Conclusion and Future Work

This study reports a practice-based case of designing and implementing a digital textbook for introductory data science education that integrates Excel, Tableau, and opens data. The main contributions are as follows: (1) proposing a digital textbook structure that integrates explanations of

statistical concepts, step-by-step procedures for Excel/Tableau, practice datasets, and instructional videos; (2) articulating a learning workflow that guides students from data preparation and descriptive statistics in Excel to visualization in Tableau, as well as to interpretation and evidence-based explanation in writing; and (3) organizing practitioner insights from classroom operation in a transferable form. Future work will develop a second edition and analyze the effectiveness of this approach through student and instructor surveys and related evaluations.

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