IIAI Open Conference Publication Series
IIAI Letters on Institutional Research
Vol. 005, LIR469
DOI: https://doi.org/10.52731/lir.v005.469

Examining Current State of Data Science Education in High Schools and Higher Education Institutions

Eriko Tanaka *, Takaaki Ohkawauchi *

Abstract

Data science education (DSE) has become a global trend, and in Japan, it is gaining increasing emphasis, as evidenced by the introduction of accredited programs for higher education institutions. However, despite the proactive establishment of institutional frameworks, there has been limited discussion regarding the educational effectiveness within individual institutions, such as high schools and universities, as well as the continuity between these educational stages. This study administered a data science comprehension assessment to 406 high school and 1,652 first-year university students in early April 2025, prior to receiving formal DSE at their respective institutions. While university students scored slightly higher than high school students, the overall comprehension levels were low, and differences across departments, particularly between STEM and non-STEM students, were negligible. These results suggest the need to reassess the respective roles of individual educational institutions, strengthen curricular continuity, and refine the specific content delivered at each stage.

Keywords: curriculum management, data science education, MDASH, non-STEM, STEM

1 Introduction

As an inherently interdisciplinary field, data science has attracted considerable interest across a wide range of disciplines [1]. Consequently, numerous data science education (DSE) initiatives have emerged. Beyond technical competencies such as data engineering and data analysis, effective data scientists must also possess analytical thinking and sensitivity to context for translating analytical results into problem-solving and decision-making in real-world business settings [2]. Modern frameworks for mastering data science have typically identified three core components: computer science, mathematics and statistics knowledge, and domain-specific expertise [3][4]. These capabilities are no longer a province of specialists; rather, they have become essential skills for functioning in contemporary society. Accordingly, DSE programs targeting non-Science, Technology, Engineering, and Mathematics (STEM) students and K–12 learners have been launched in various countries around the globe.

This trend has also influenced DSE in Japan, marked by the launch of the Mathematics, Data Science and AI Smart Higher Education (MDASH) approval program in 2021 [5]. The program is designed to provide data science literacy education across the academic continuum, with the first half of the curriculum targeting elementary through high school, and the latter half implemented in higher education institutions. Accordingly, the government certifies higher education institutions that meet the established educational standards for DSE [6]. According to the latest

* Nihon University, Tokyo, Japan

report, of the approximately 800 higher education institutions nationwide, 493 have been certified at the literacy level and 166 at the advanced literacy level [7]. Moreover, many institutions that have not yet been approved are actively pursuing MDASH certification. Essentially, DSE in Japan is increasingly expected to span a broad range of academic fields and begin at earlier educational stages. Educational institutions are now developing curricula and systems aligning with national standards and the overall framework for DSE implementation is beginning to take shape.

2 Related Work

As demand for data science increases, the academic field of DSE is rapidly evolving [8]. While numerous studies have examined key topics such as educational objectives, program design, curriculum development, and career pathways [9][10][11][12], this study identifies three critical issues that remain insufficiently addressed.

2.1 Independence of Scope

Previous research on DSE has often addressed target audiences separately, based on age groups or disciplinary backgrounds—for example, focusing individually on STEM and non-STEM students, or K–12 learners. Conversely, the MDASH framework defines common achievement goals for each literacy and advanced level, regardless of the academic domain. This approach necessitates a unified discourse grounded in shared curricula and learning outcomes that can accommodate students from diverse academic backgrounds.

2.2 Insufficient Evaluation of DSE Programs

Although DSE has only recently emerged as a prominent trend in the education sector, and limited time has passed for longitudinal assessment, comprehensive evaluation regarding the effectiveness of program and curriculum implementation remains lacking. While some studies have attempted to assess DSE, these evaluations are typically confined to individual courses or focus narrowly on tool usage and data handling techniques, addressing only a subset of the broader data science competencies outlined [13][14][15]. Presently, no research has evaluated the overall effectiveness of entire programs or curricula holistically.

2.3 Consideration of Curriculum Connectivity

As noted in the previous section, DSE is intended to be delivered through a continuous curriculum spanning from elementary school through higher education. Therefore, evaluating its significance or effectiveness based solely on outcomes from a single educational stage is insufficient without accounting for the vertical connectivity of the curriculum. For example, insufficient learning outcomes observed in higher education may stem from challenges faced at the high school level, or even earlier in elementary or middle school. Conversely, even if university students demonstrate adequate proficiency in data science, it cannot be attributed solely to higher education instruction without first confirming that these skills were not already well developed in prior educational stages.

Based on the above considerations, a comprehensive evaluation of DSE entails an assessment of students' proficiency in data science knowledge and skills across a range of disciplinary backgrounds. Moreover, these evaluations should not be limited to a single educational institution, but rather examine curricular continuity and enable comparisons across multiple educational stages, including both high school and higher education.

3 Research Methodology

This section outlines the target participants, research plan, and content used to evaluate the effectiveness of DSE in Japan.

3.1 Target Students

As discussed in the previous section, prior research has faced limitations, such as insufficient diversity among student populations and the isolated implementation of studies, with limited emphasis on curricular continuity.

The primary site of this research is the College of Humanities and Sciences at Nihon University, a multidisciplinary faculty comprising 18 departments across the humanities, social sciences, and natural sciences, with approximately 2,000 students enrolled per academic year [16]. Additionally, following MDASH approval in 2024, all incoming students are required to complete three courses aimed at achieving data science literacy, starting from the 2025 academic year.

Furthermore, Nihon University not only has the largest student population in the country but also maintains a network of affiliated high schools, enabling the inclusion of numerous affiliated high school students as research subjects. As many of these students subsequently enroll at the university, this framework enables a longitudinal research design that tracks the same individuals from high school through university—an approach rarely employed in prior DSE research.

3.2 Research Plan and Schedule

This study aims to investigate the learning attitudes and educational effectiveness of data science instruction in high schools and higher education institutions. Building on the premise of assessing effectiveness through pre- and post-surveys, this study specifically focuses on the following two perspectives.

(a) Assessment of data science academic proficiency among students at the point of entry to each educational institution

To evaluate the effectiveness of DSE across different educational institutions, the study initially assessed and compared the levels of data science comprehension among incoming students at both high school and university entry points, using the same set of assessment indicators.

(b) Assessment of comprehension levels upon completion of DSE at each educational institution

In high schools, students are required to acquire knowledge and skills related to data science as part of the government-designated "Information" subject. Contrastingly, universities lack nationally-mandated common courses such as those in high schools. At Nihon University, all students are expected to achieve literacy in data science through three mandatory courses that must be completed by the end of the first semester of the sophomore year. Therefore, comprehension assessments are conducted at the conclusion of the first semester of the sophomore year.

The research plan summarizing Sections 3.1 and 3.2 is illustrated in Figure 1.

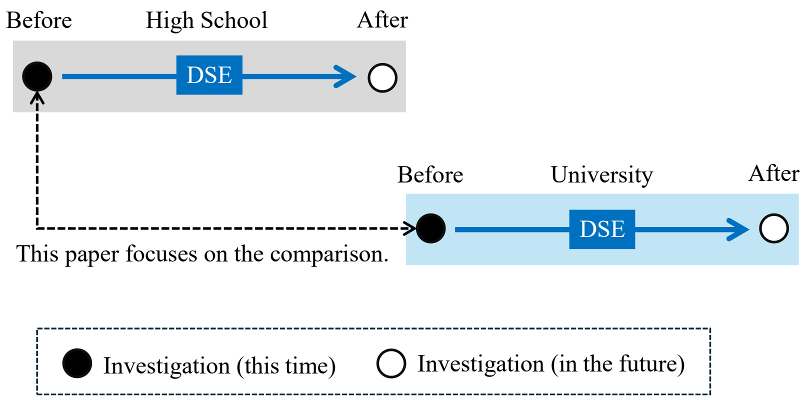


Figure 1: Research Plan

In conclusion, this research is an ongoing, multiyear study that tracks high school and university students enrolled in 2025 through their graduation. Additionally, it monitors students' transitioning from affiliated high schools to this university until they complete their DSE. The study specifically focuses on assessing and comparing data science comprehension levels of current high school students and university entrants.

Japan revised its high school curriculum guidelines in 2022 to incorporate a significantly larger amount of data science- and AI-related content into mathematics and information subjects. As a result, this year's university freshmen—unlike previous cohorts—have all received DSE. Therefore, measuring their comprehension levels at the point of university entry allows for an assessment of the effectiveness of new high school DSE programs, making it an ideal time to initiate the investigation.

3.3 Measurement Methodology for Data Science Comprehension

To evaluate DSE in educational institutions, a comprehensive assessment test was developed based on the MDASH standard curriculum [17]. The literacy-level curriculum comprises four major categories, numbered 1–4. Considering that Category 4 is designated as optional content, the comprehension assessment test was designed based on Categories 1–3. The incoming students were administered a test consisting of 55 questions, of which 5 were selected from each topic within Categories 1-1 through 3-2, as outlined in the curriculum (Table 1).

Table 1: Content and Number of Questions in the Comprehension Assessment

<table>
<tr><th rowspan="2">Major Category</th><th rowspan="2">Subcategory</th><th rowspan="2">Number of Questions</th><th rowspan="2">Keywords of Question</th><th colspan="2">Format of Question</th></tr>
<tr><th>Keyword</th><th>Description</th></tr>
<tr><td rowspan="4">1.
Data and AI Utilization in Society</td><td rowspan="4">1-1.
Changes Occurring in Society</td><td rowspan="4">5</td><td>Exabyte (EB)</td><td>✓</td><td></td></tr>
<tr><td>Characteristics of Big Data</td><td>✓</td><td></td></tr>
<tr><td>Society 5.0</td><td></td><td>✓</td></tr>
<tr><td>Multimodal AI Technology</td><td></td><td>✓</td></tr>
</table>

Major Category	Subcategory	Number of Questions	Keywords of Question	Format of Question	
				Keyword	*Description*
			Strong AI	✓	
	1-2. Data Utilized in Society	5	Sample survey	✓	
			Metadata		✓
			SQL	✓	
			Segmentation	✓	
			Open Data		✓
	1-3. Application Domains of Data and AI	5	Value Chain	✓	
			POS System	✓	
			Chat Bot		✓
			Churn Analysis		✓
			Generative AI		✓
	1-4. Technologies for Data and AI Utilization	5	Modeling		✓
			Scatter Plot	✓	
			Morpheme Analysis	✓	
			RPA		✓
			Hallucination	✓	
	1-5. Field Applications of Data and AI Utilization	5	CRISP-DM		✓
			Digital Transformation (DX)		✓
			Exploratory Data Analysis (EDA)		✓
			Long Tail Business Model		✓
			Explainable AI (XAI)		✓
	1-6. Latest Trends in Data and AI Utilization	5	Dynamic Pricing		✓
			Recommendation System		✓
			Transfer Learning		✓
			Reinforcement Learning		✓
			Large Language Model (LLM)		✓
	Subtotal	30			
2. Data Literacy	2-1. Reading Data	5	Ordinal Scale	✓	
			Median		✓
			Histogram		✓
			Variance and Standard Deviation		✓
			Confounding		✓
	2-2. Explaining Data	5	Box Plot		✓
			A/B Test		✓
			Chartjunk		✓
			Reading Chart		✓
			Presentation		✓
	2-3.	5	JSON Format	✓	

Major Category	Subcategory	Number of Questions	Keywords of Question	Format of Question	
				Keyword	*Description*
	Handling Data		AVERAGE Function (Excel)	✓	
			RANK Function (Excel)		✓
			BI Tool		✓
			CSV Format		✓
	Subtotal	15			
3. Considerations in Data and AI Utilization	3-1. Considerations When Handling Data and AI	5	ELSI		✓
			GDPR		✓
			Data Fabrication		✓
			Data Bias		✓
			Responsibility of Using AI		✓
	3-2. Considerations for Data Protection	5	Information Security	✓	
			ISO	✓	
			Anonymized Processed Information		✓
			Data Breach		✓
			Ransomware		✓
	Subtotal	10			
Total		55			

Regarding the content of the questions, all items were formatted as multiple-choice questions with four options. The questions were based on keywords presented in the MDASH model curriculum [17] and standard textbooks [18]. The questions were designed in two formats: one provided explanatory text and required students to identify the correct keyword, while the other presented keywords and asked students to select an appropriate explanatory description. Provided below are examples of a question from each format.

Q2 (from 1-1). Select Keyword
Select the item that is NOT included among the 3Vs that characterize Big Data.

1. Variety 2. Velocity 3. Visuality 4. Volume

Q55 (from 3-2). Select Description
Select the most appropriate description of ransomware.

1. A computer virus that steals information by monitoring keyboard and mouse operations
2. A system that directs users to counterfeit websites designed to appear legitimate in order to elicit information input
3. Software that encrypts files making them unusable and demands payment for their recovery
4. Software that covertly utilizes a user's system for cryptocurrency mining without their knowledge

4 Results and Discussion

Overall, 406 high school and 1,652 university students from the institution completed the 55-question assessment described in the previous section. The test was administered in early April 2025, before the students received DSE at their respective educational institutions. It is important to note that the participants were fully informed in advance that the test was part of a baseline investigation aimed at measuring comprehension and providing foundational data for future curriculum development, with no impact on their academic grades.

4.1 Results of Comprehension Assessment

Table 2 presents the results of the comprehension assessment for high school and university students based on the 55-question test described in Table 1.

Table 2: Mean Score of the Comprehension Assessment

Major Category	Subcategory	High School Students	University Students			
			Total	*Humanity*	*Social Sciences*	*Natural Sciences*
1	1-1	1.12	**1.31****	1.25	1.29	1.43
	1-2	**2.06****	1.89	1.89	1.89	1.89
	1-3	1.74	**2.01****	1.95	2.05	2.01
	1-4	1.26	**1.65****	1.61	1.59	1.82
	1-5	**1.55***	1.46	1.47	1.44	1.50
	1-6	1.78	**1.84**	1.93	1.83	1.73
	Subtotal	9.51	**10.16****	10.10	10.10	10.38
2	2-1	1.83	**1.86**	1.82	1.85	1.95
	2-2	2.61	**2.78****	2.75	2.71	3.00
	2-3	1.54	**1.70****	1.68	1.74	1.63
	Subtotal	5.98	**6.35****	6.25	6.31	6.59
3	3-1	1.74	**1.91****	1.97	1.86	1.92
	3-2	1.33	**1.54****	1.60	1.49	1.57
	Subtotal	3.07	**3.45****	3.57	3.35	3.49
Total		18.56	**19.95****	19.92	19.75	20.46

Note. * indicates significance at the 5% level and ** indicates the 1% level for the Welch's test.

For university students, the results are further categorized into three academic streams—humanities, social sciences, and natural sciences—allowing for a more detailed analysis. For each category, the mean test scores of high school and university students are compared, with higher scores highlighted in bold. Additionally, Welch's test was employed for significance testing, because equal variance could not be assumed between the datasets for some question categories.

As shown in Table 2, university students outperform high school students in nearly all categories.

However, in Categories 1-2 and 1-5, high school students achieved higher mean scores, while in Categories 1-6 and 2-1, university students scored higher on average, although the differences were not statistically significant. All these categories exhibited unequal variance in responses, indicating differing levels of variability between groups.

When measuring the discrimination index for each question using Item Response Theory, although some questions exhibited low discrimination, none of the categories demonstrated extremely small or negative values overall. Additionally, while the means and variances differed across question categories, the normality of the score distribution was confirmed for all categories using the Kolmogorov–Smirnov test. Although the test appears to have been somewhat challenging for students from the perspective of measuring comprehension, there were no significant issues with the questions. Figure 2 presents a histogram showing the distribution of total scores for high school and university students. As illustrated in Table 2, the mean score for university students was 19.95, slightly exceeding that of 18.56 for high school students. However, the histogram reveals little difference between the distributions of their scores.

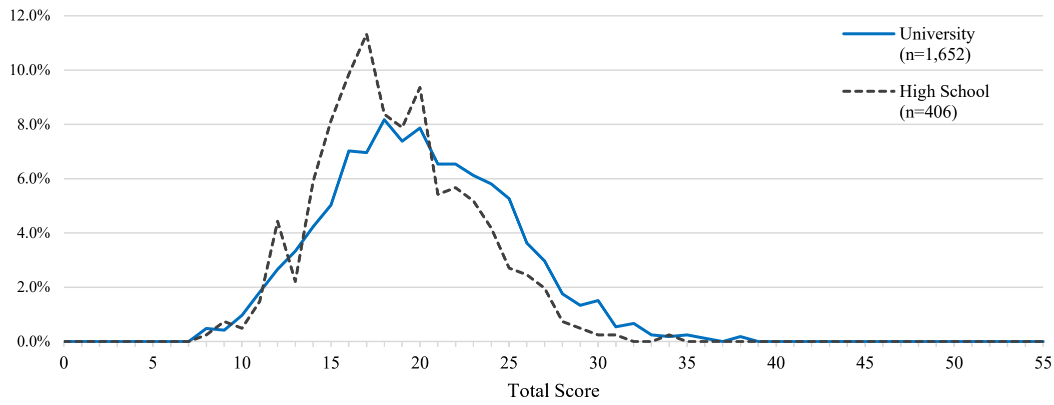
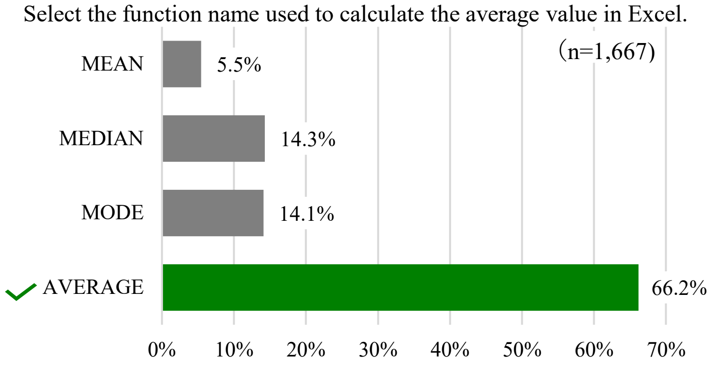


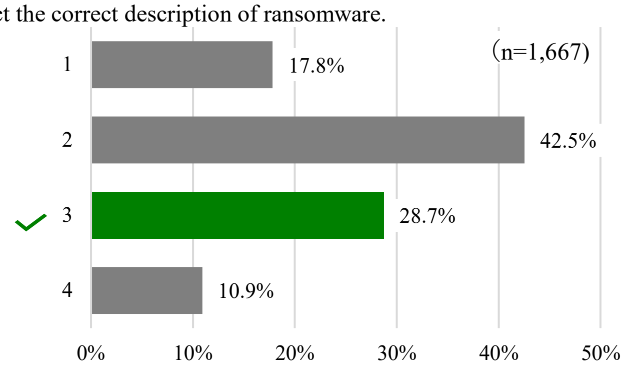
Figure 2: Score Distribution of Total Points in the Comprehension Assessment

4.2 Discussion

Overall, the level of comprehension demonstrated in the data-verification test was relatively low. As the test consisted of 55 multiple-choice questions with four options each, a score of 13.75 points (25%) was expected from random guessing. However, the mean scores were 18.56 (33.75%) for high-school students and 19.95 (36.27%) for university students, which did not substantially exceed this value.

While it could be argued that the questions were challenging, Figure 3 reveals that even for items requiring the identification of Excel function names, more than one-third of university students responded incorrectly. Furthermore, for the question asking students to select the correct description of ransomware, the correct response rate remained at only 28.7%, with 42.5% of students selecting the incorrect description of phishing sites. This occurred despite both ransomware and phishing sites being terms covered in the "Information" subject textbooks [19][20].





1. A computer virus that steals information by monitoring keyboard and mouse operations
2. A system that directs users to counterfeit websites designed to appear legitimate in order to elicit information input
3. Software that encrypts files making them unusable and demands payment for their recovery
4. Software that covertly utilizes a user's system for cryptocurrency mining without their knowledge

Figure 3: Example of Correct Answer Rates Among University Students

Although this test was administered prior to students receiving university-level DSE, these concepts may have been learned during their studies. However, the current comprehension test scores suggest that university students have not adequately understood the content from high school textbooks and were significantly below the expectations of the team that designed the university DSE curriculum and courses. During the test development phase, keywords were selected as question targets, expecting that simpler questions would yield correct answer rates exceeding 80%, while slightly more challenging questions would still achieve correct answer rates above 50%.

Next, the association between high school and higher education DSE was addressed. While not all high school graduates thoroughly master the data science content covered in secondary education, ideally, university-level DSE should build upon the knowledge foundation established in high school (Figure 4). Higher education curricula should prioritize addressing content areas where overall comprehension is lacking, while also introducing advanced concepts that extend beyond high school curriculum. According to previous research, students are expected to have engaged with all areas of the high school curriculum at a substantial level, with the exception of 1-6, 3-1, and 3-2 [21]. However, as shown in Table 2, although significant differences were confirmed for most items owing to the large sample size, the actual differences in the mean scores are minimal.

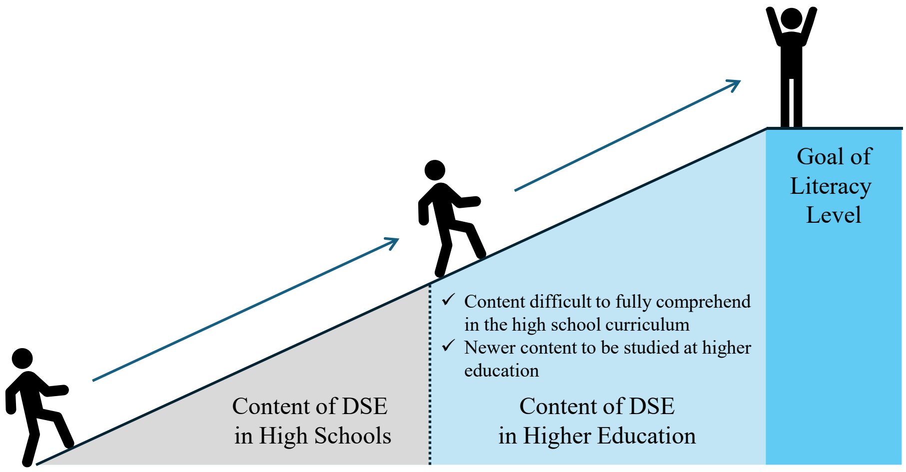


Figure 4: Ideal Curriculum Connectivity of DSE

There are two possible explanations for this. First, while students may have encountered these topics in high school, the content may have exceeded their capacity, hindering sufficient understanding. In this case, a potential approach would be to further narrow the scope of learning content and topics to ensure they remain within a range that students can effectively comprehend. The second possibility concerns issues on the educators' side: although the topics are included in the curriculum and textbooks, students may not be receiving adequate instruction due to time constraints in class schedules or limitations in teachers' knowledge and experience. As mentioned previously, similar to when information science was introduced in Japan or programming education became mandatory, some teachers were required to teach subjects that they had not studied themselves. In this study, comprehension levels were assessed at the time of entry into both high school and university, examining the differences to discuss the current state of DSE at the high school level. However, it is believed that more detailed investigations—such as teacher surveys and classroom observations—are necessary to better understand the educational practices being implemented in high school settings.

Furthermore, an examination of the comprehension test results—out of 55 points—by academic stream, as shown in Table 2, reveals that humanities students averaged 19.92 points, social sciences students 19.75 points, and natural sciences students 20.46 points, confirming that no substantial differences were observed between STEM and non-STEM disciplines. In Japanese high schools, students are typically divided into humanities and science streams in their second year, leading to different course selections; however, within the scope of this comprehension assessment administered at university entry, the differences in achievement rates between these streams were virtually negligible. At the university level, students enroll in specialized courses tailored to their respective departments, resulting in greater differentiation in course selection and learning content compared with high school students. To determine at which learning stage and to what extent these differences emerge, periodic comprehension assessments are conducted, similar to the present study, throughout the mandatory data science courses at the university.

5 Conclusion

To examine the current state of DSE and its continuity between high school and university, this study administered a data science comprehension assessment to students entering both educational institutions. The results revealed statistically significant differences, with university students performing better on many learning items specified in the MDASH literacy level; however, the actual magnitude of these differences were minimal.

Additionally, when providing DSE aimed at common achievement goals, the topic of tailoring instruction to students' specializations and interests frequently arises. Rather than categorizing by specific departments or specialized fields, many studies have broadly conceptualized this division as STEM versus non-STEM. However, the findings show that there was virtually no difference at the time of university admission, implying that students are beginning from nearly the same starting point. To examine this point comprehensively, it will be necessary to verify through teacher interviews and surveys whether and how teaching approaches differ between STEM and non-STEM students in high school classrooms, or whether the instruction is delivered uniformly.

Based on these findings, two future research directions were identified. The first research direction is to comprehensively capture the current state and future of DSE through continuous investigation of a larger student population. Therefore, it is necessary to expand the survey targets to include more high school and university departments, thereby making the evaluation more multifaceted and reliable. The second research direction addresses the limitation that, while comprehension assessments provide fair and objective indicators of learning outputs at a specific point in time, test results alone are insufficient to evaluate the relationship between actual educational content and its effectiveness. It is imperative to conduct a more detailed analysis linking learning content to outcomes by administering surveys and conducting interviews with teachers and students, thereby gaining deeper insights into the practical implementation of DSE.

The ultimate goal is to more clearly define the roles and achievement objectives for each educational stage in DSE and to propose and develop a comprehensive DSE curriculum for Japan that emphasizes curricular continuity across educational institutions.

Acknowledgement

This work was supported by JSPS KAKENHI Grant-in-Aid for Scientific Research C 25K06551.

References

[1] D. Andrea, L. Paul, C. Lillian and S. Christian, “ACM Task Force on Data Science Education:

Draft Report and Opportunity for Feedback, " Proc. the 50th ACM Technical Symposium on Computer Science Education, 2019, pp. 496-497.

[2] A. Takemura, S. Izumi, K. Saito, T. Himeno, H. Matsui and H. Date, "Shiga University Model of Data Science Education (in Japanese)," Proc. the Institute of Statistical Mathematics, 2018, pp.63-78.

[3] D. Conway, "The Data Science Venn Diagram. Retrieved from Drew Conway Data," Data Consulting, http://drewconway.com/zia/2013/3/26/the-data-science-venn-diagram (accessed 15-Apr-2025)

[4] J. Ullman, "What Is Data Science? A Turing Award Winner Shares His View," BIGDATAWIRE, https://www.bigdatawire.com/2021/08/18/what-is-data-science-a-turing-award-winner-shares-his-view/ (accessed 15-Apr-2025)

[5] Ministry of Education, Culture, Sports, Science and Technology (MEXT), "Approved Program for Mathematics, Data Science and AI Smart Higher Education (in Japanese)," https://www.mext.go.jp/a_menu/koutou/suuri_datascience_ai/00001.htm (accessed 15-Apr-2025)

[6] Director General for Science, Technology and Innovation Policy, Cabinet Office, "Considerations for Developing the ' Approved Program for Mathematics, Data Science and AI Smart Higher Education' (in Japanese)," National Diet Library, https://warp.ndl.go.jp/info:ndljp/pid/11451087/www.kantei.go.jp/jp/singi/ai_senryaku/suuri_datascience_ai/dai1/siryou1-2.pdf (accessed 15-Apr-2025)

[7] Ministry of Education, Culture, Sports, Science and Technology (MEXT), "List of Approved and Selected Institutions (in Japanese)," https://www.mext.go.jp/a_menu/koutou/suuri_datascience_ai/mext_00005.html (accessed 15-Apr-2025)

[8] K. Mike, B. Kimelfeld, and O. Hazzan, "The Birth of a New Discipline: Data Science Education," Harvard Data Science Review, vol.5(4), 2023, pp.1-26.

[9] L. Barboza and E. Teixeira, "Effect of data science teaching for non-STEM students: A systematic Literature Review ," Proc. the 15th International Conference on Software Engineering Advances, 2020, pp.118-122.

[10] M. Foster and Z. Tasnim. "Data science and graduate nursing education: a critical literature review," Clinical Nurse Specialist, vol.34(3), 2020, pp.124-131.

[11] H. Wu, "Systematic Study of Big Data Science and Analytics Programs," Proc. 2017 ASEE Annual Conference & Exposition, 2017; doi:10.18260/1-2—28900.

[12] D. Preiss, J. Sperling, R. M. Huang, K. Bradbury, T. Nechyba, R. Calderbank, G. Herschlag and J. S. Borg, "Where Data Science and the Disciplines Meet: Innovations in Linking Doctoral Students with Masters-Level Data Science Education," Harvard Data Science Review 6 (4), 2024, pp.1-64.

[13] J. Ebbeler, C.L. Poortman, K. Schildkamp and J. M. Pieters, "The effects of a data use intervention on educators' satisfaction and data literacy," Educational Assessment, Evaluation and

Accountability, vol.29, 2017, pp.83-105.

[14] N. Kayaki, C. Hayashi, Y. Higuchi, H. Nishioka and M. Kobayashi, “Educational Effect Measurement and Assessment of Data Literacy Education for Students Majoring in Business Administration (in Japanese),” The Journal of Business Studies Ryukoku University, vol.63(3・4), 2024, pp.1-14.

[15] A. Khalemsky, R. Gelbard, and Y. Stukalin, “Constructing a Course on Classification Methods for Undergraduate Non-STEM Students: Striving to Reach Knowledge Discovery,” Journal of Statistics and Data Science Education, vol.33(1), 2025, pp.68-76.

[16] E. Tanaka and T. Ohkawauchi, “Analysis of Discrepancies in Learning Awareness of Data Science Across Disciplines – a Case Study of Nihon University, College of Humanities and Sciences –,” IIAI Letters on Institutional Research, vol.5, 2024, pp.1-12.

[17] Mathematical, Data Science, and AI Education Enhancement Hub Consortium, “Literacy Level Model Curriculum Corresponding Materials (in Japanese),” http://www.mi.u-tokyo.ac.jp/consortium/e-learning.html (accessed 15-Apr-2025)

[18] G. Kitagawa and A. Takemura, ed., Data science as the liberal arts (in Japanese), Kodansha, 2024.

[19] N. Akazawa, H. Akaike, Y. Shibata, H. Kakuda and Y. Nakayama, “Changes in Terms which Appear in Informatics Textbooks at High Schools in Japan (in Japanese),” IPSJ Transactions on Computers and Education, vol.10(1), 2024, pp. 13-24.

[20] researchmap, “Terminology from All Information Subject Textbooks (in Japanese),” https://researchmap.jp/n-akazawa/works/43305921?lang=en (accessed 15-Apr-2025)

[21] S. Ohashi, “Connectivity Between High School and University Data Science Education(in Japanese),” RIMS Kokyuroku, vol.2236, 2022, pp.1-8. https://repository.kulib.kyoto-u.ac.jp/dspace/handle/2433/282945?mode=full&locale=en (accessed 15-Apr-2025)