International Journal of Educational Media and Technology
2021, Vol. 15, No. 1 pp.34-45

The Influence of an Adaptive Learning Support System on the Lesson Design and Practice of Elementary School Teachers

Wakio Oyanagi
Kansai University, Osaka, Japan
oyanagi@kansai-u.ac.jp

The purpose of this study was to clarify how an adaptive learning environment with artificial intelligence diagnosis was used during mathematics lessons by students and teachers and to clarify how its use led to learning outcomes. Forty-three elementary schools in City A, in Japan, participated in this project for three years. It was found that schools that were successful in using this system were doing the following five things. 1) Utilizing the information of this system in the analysis of examples and teaching materials used in the class, 2) visualizing the thinking process in the child and making it correspond to the results returned by the system, 3) making time for the student to read and understand the recommendation information returned to them by the system in class, 4) making use of an individual child's learning style in teaching, and 5) using information from this system in discussions with parents. This model has shown that principals and lead teachers tried to relate evidence-based practice and evidence-informed practice well and tried to think about the meaning and method of using data together with other teachers. Teachers have come to think of "assessment of learning" as "assessment for learning" when it comes to data usage and began to associate it with improving the assessment literacy of teachers and their students.

Keywords: Adaptive Learning, Mathematics Education, Teacher Professional Development

Introduction

Adaptive learning is a learning environment that uses information and communication technology (ICT) to facilitate comprehension and retention based on the unique needs of the learner. An adaptive learning system is unique in terms of its level of detail and design. It tends to be constructed from three components: "Content," "Learner," and "Instructional Method." Practical research and development on adaptive learning systems have been conducted in higher education (Dziuban, Howlin, Moskal, Johnson, Parker, & Campbell 2018). The research on adaptive learning is often understood to be an extension of CAI research based on behaviorism (Mavroudi, Giannakos, & Krogstie 2017). Recent adaptive learning systems have been linked with the personalized learning approach by utilizing big data and artificial intelligence (AI)(Hariyanto, Triyono, & Köhler 2020). It has been able to adapt to the preference and learning style of the learner. Adaptive learning systems have become able to help learners to take ownership of their learning (Nuri & Nese 2013).

Adaptive learning is not only gaining interest in higher education but also in K-12 education. According to the NMC Horizon Report (2015), adaptive learning and components of adaptive learning are identified as key trends in important developments in educational technology for K-12 education. A technology-based personalization intervention within an intelligent tutoring system for secondary mathematics is used to adapt instruction to students' personal interests (Walkington 2013). Moltudal (2020) attempted to obtain a comprehensive understanding of how a systematic implementation of adaptive learning technology influenced the learning outcomes, learning environment, and motivation of 10- to 12-year-old pupils in mathematics.

To further investigate research trends in this field, we searched the ERIC educational research database for peer-reviewed papers that included the term "adaptive learning" in the abstract at the end of March 2021. A total of 447 papers were found. In the last ten years alone, 290 peer-reviewed papers have been published. Of the 447 articles, 40 were found to focus on secondary education, 34 on primary education, and 9 on primary through secondary education. The following trends were identified from the objectives of the 40 papers on secondary education and 34 papers on primary education.

1. Research on the application of adaptive learning to the development of an e-learning system. For example, “Developing an Adaptive E-Learning Environment Using Cognitive and Noncognitive Parameters,” “Adaptive e-learning can be used to personalize learning environment for students to meet their individual demands,” “Automatic Personality Identification Using Students' Online Learning Behavior,” and “Regulating Distance to the Screen While Engaging in Difficult Task.”
2. Research on the effects of individual characteristics, needs, interests, cooperation learning, learning disabilities, gender, and culture-based approaches on learning outcomes using adaptive learning systems. For example, “Using Adaptive Learning Technologies to Personalize Instruction to Student Interests,” “Using Large Data to Analyze the Effect of Learning Attitude for Cooperative Learning between the High Achievement Students and the Low Achievement Student,” “Reading Achievement, Mastery, and Performance Goal Structures among Students with Learning Disabilities,” “Adaptive Web-Assisted Learning System for Students with Specific Learning Disabilities,” “Gender Differences in the Use and Benefit of Advanced Learning Technologies for Mathematics,” and “A Cross-Cultural Analysis of Achievement and Social Goals among Chinese and Filipino Students.”
3. Research on methods for guiding the development of higher-order thinking and self-regulated learning using adaptive learning systems. For example, “A Framework of Smart Pedagogy Based on the Facilitating of High Order Thinking Skills,” “The Relationship between Self-Efficacy and Self-Regulated Learning in One-to-One Computing Environment,” and “Mine the Process: Investigating the Cyclical Nature of Upper Primary School Students' Self-Regulated Learning.”
4. Research on the use of adaptive learning systems to guide effective learning in subjects such as science and mathematics. For example, “An Adaptive Scaffolding E-Learning System for Middle School Students' Physics Learning,” “A Multimedia Adaptive Tutoring System for Mathematics That Addresses Cognition, Metacognition and Affec,” and “Adaptively Ubiquitous Learning in Campus Math Path.”
5. Research on how to use an adaptive learning support system that is also related to teacher education. For example, “The Role of Academic Buoyancy and Emotions in Students' Learning-Related Expectations and Behaviours in Primary School,” “Mathematical Pedagogical Content Knowledge of Early Childhood Teachers: A Standardized Situation-Related Measurement Approach,” and “Adapting a Portion of the Patterns of Adaptive Learning Scales for Research in Turkish Schools.”

As a result of the literature search, Trend 5 was found to have a lack of research in comparison to the four other research trends.

Smith (2018) explained that technology was viewed as an integral part of instruction in K-12 mathematics education. “There is evidence to support the positive impact technology has on mathematics achievement. In the context of K-12 mathematics education, there are a number of different types of technology commonly used. Calculators, interactive whiteboards, computer algebra systems, dynamic geometry environments, and adaptive learning programs are some of the technologies used in K-12 mathematics classrooms.” He wrote that “not all teachers are prepared to implement technology tools such as adaptive learning programs effectively. There is also a lack of research that specifically looks at preparing preservice teachers to use adaptive learning programs in the K-8 mathematics classroom.”

Symes and Putwain (2016) pointed out that teachers might use value-promoting messages (VPMs) to communicate to students the value and importance of their forthcoming examinations in the hope that they would adopt adaptive learning and study behaviors.

Konert, Richter, Mehm, Gobel, Bruder, and Steinmetz (2012) indicated that the basis for individual students' instructional support by teachers was an individual diagnosis of each one's learning advances and difficulties. Even though sophisticated diagnostic tools do exist, it remains an open question as to how diagnosis and learning can be merged into a consistent pedagogical method to support both teachers and students with feedback about the learning process.

Based on the above, this study posed the following research question, considering that it would be useful to accumulate research findings in the Japanese context. “How can an adaptive learning environment with AI diagnosis be utilized in math lessons in elementary schools?”

The purpose of this study is to clarify how an adaptive learning environment with AI diagnosis is used during a given math lesson by students and teachers, and to clarify how its use led to learning outcomes. We aim to clarify what kind of guidance and learning environment settings are required for different learners when this system is used in the classroom. This article also discusses what kinds of expertise and skills are required for teachers to operate this system effectively

Research Design and Methods

This study is part of a joint research project with City A and Dai Nippon Printing Co., Ltd. It is concerned with how to implement adaptive learning effectively in an environment that is different from the e-learning and one-to-one computing environments studied in most of the previous international research on adaptive learning systems and programs. The learning activity studied here is a learning program in which students and teachers reflect on learning outcomes in a math class, using paper tests created with an adaptive learning support system and paper exercises, as well as comments provided by individual learning diagnostics. After a one-year preparation phase, the study was carried out in an operational evaluation phase of two years. This research focused on analyzing the mathematics learning of students and utilizing that information to improve teaching. Many local governments and schools participated in the research because it did not require an expensive environment with special ICT equipment.

Regarding the research method, information was collected and analyzed in two ways to evaluate how the system operates.

First, we gathered and analyzed the relationship between each student's unit mathematics test results and the result of the end of term test for the same subject for two years as a direct assessment method. Second, we analyzed the following three pieces of information collected by questionnaires as an indirect approach. 1) Students' opinions on the utilization of "recommendation sheets" and evaluation comments, 2) the opinions of teachers concerning the operation of this system, and 3) teachers' opinions on the professional learning program.

City A introduced a system of adaptive learning support for the fourth grade in three schools on a trial basis in the academic year 2016 and subsequently began to use the system for all students in the city from the fourth to the sixth grade from September 2017 (about 2,700 students in each of the fourth, fifth, and sixth grades). This action focused on how a system of adaptive learning support could be used to raise the assessment literacy of teachers and foster the ability of students to learn by themselves.

Based on data generated after three years of implementation, this study intended to clarify both the potential of and problematic issues related to how the system is being utilized by teachers and the reception of the system by schools.

In addition, raising the skills of the teachers was an urgent issue for City A, where an increasing number of teachers were relatively inexperienced. Therefore, City A tried to provide an environment that allowed young teachers to utilize data to grasp the condition of the classes in which they teach and to encourage mutual learning between teachers in different year groups and at different schools. Further, the study aimed to clarify effective professional learning content and methods for achieving this objective.

Figure 1 illustrates the contents and attributes of the system to support the activities of students and teachers.

First, a unit of math was taught in the classroom (Figure 1A). Then, the students took a unit test, which was developed to assess the extent to which they have met the targets for the unit. The unit test comprised ten sections: 1) six sections with basic standard questions based on the government's curriculum guidelines, requiring mastery of the topic learned; 2) two sections designed to foster good judgment, in which textbook questions that are not clear or where lack of attention could lead to incorrect answers were highlighted, and proper interpretive skills were instilled; and 3) two sections based on materials associated with the topics learned and designed to stimulate thinking skills, focusing on questions requiring problem-solving abilities rather than just knowledge (Figure 1B). The end-of-semester test comprised 20 sections. These included 12 sections with questions based on standard learning abilities, four with judgment-based questions, and four with questions that require thinking skills (Figure 1E).

After completion of the unit test, the test papers were scanned using a system installed at the school and marked automatically. Relevant data were transmitted to a cloud server over a network. The data were analyzed by an AI-based system, not only to identify questions that have been answered incorrectly but also to highlight the level of the pupils' understanding related to questions answered correctly. That is, in each unit test, we analyzed not only the incorrect answers, but also determined whether we could fully understand the problems that were solved correctly using item reaction theory (IRT) and latent rank theory (LRT).

IRT is used to estimate how the key responses to problematic items are affected by error factors (e.g., distortion, ambiguity, and difficulty) and the pupil's actual abilities and characteristics. LRT is an individual latent characteristic model developed by Associate Professor Kojiro Shojima in Japan. It is a theory that can be used to evaluate problem difficulty analysis and response tendency simultaneously, and it can suggest stability and potential ability by detecting issues such as affiliation probability to each step. (Shojima 2007, Reckase 2009).

We recommended assignments for student improvement according to the individual degree of understanding and points at which a given student had trouble; based on this, we provided the students with comment sheets. Then, based on the student's answer pattern, the system selected items with differing degrees of difficulty and performed a test. In this research, following the test, we used a system that provided evaluation information and learning materials based on the needs of each individual (Figure 1C).

After analyzing each student's level of learning, they were given a "recommendation sheet" (revision and practice worksheet with individually targeted questions) that was suited to their level of understanding and the areas that they found difficult and a "comment sheet" with words of encouragement to make them aware of their challenges.

The teacher received a record card related to the learning of each student, containing the following information. 1) whether the student has answered each question correctly or incorrectly or failed to answer it; 2) the average number of correct answers for students for each question, considering the class as a unit; 3) the average number of correct answers for each viewpoint; 4) a table showing which "recommendation sheets" the student had received; and 5) the distribution of students' ability rankings (based on LRT). The LRT identified the student's ability and potential by assigning a grade based on the analysis of question difficulty and response trends and calculating the probability of the student being assigned to each grade (Figure 1D).

The individual record card included the results of all the unit tests, the end-of-semester tests, and relevant analysis, and was thus a comprehensive source of information regarding each student's learning process and its characteristics (Figure 1G).

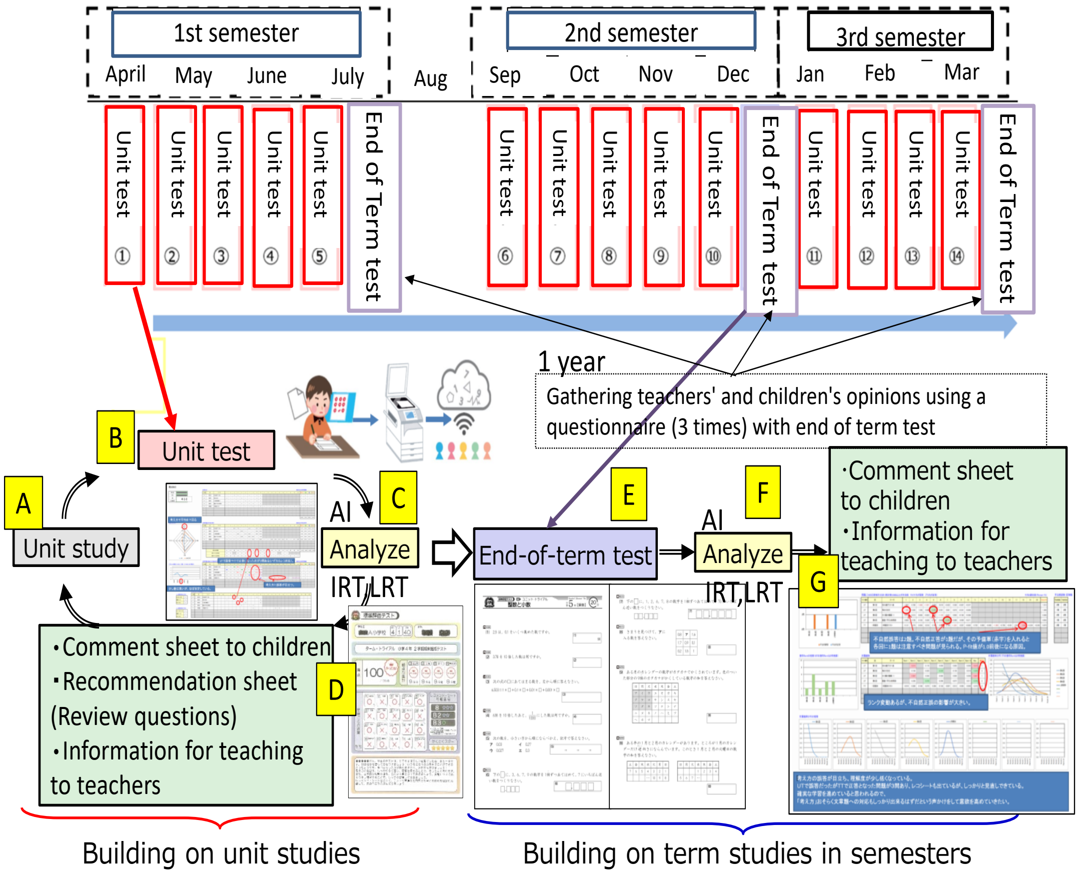

Figure 1. Overall picture of the research design and procedures

Results

We calculated the average of the deviation value and the average of the latent rank value for each year, using the end of term test score results, and the score for the year based on the student questionnaires about the city's program. For the three values, we subtracted the value in the fourth grade from that in the sixth grade for each student.

Using the school names (School 1, School 2) assigned according to change in deviation value, the schools were arranged in descending order from positive to negative. The results are shown in Figure 2.

First, we established five categories based on the number of students in the school in question with a change in the average deviation value of given sizes: a positive change of eight points or more, a positive change of four points or more but fewer than eight points, a positive change of fewer than four points, a negative change of fewer than four points, and a negative change of four points or more. Subsequently, we calculated the percentage of students in each school in the specified categories. The schools were ranked on the basis of the percentages, in descending order, starting with 1.5 points or more. The 43 elementary schools were categorized in order as School 1, School 2, and so on, starting with the schools that had the highest positive change ratios.

Next, we established five categories based on the number of students in the schools with a change in the latent rank value of given sizes: a positive change of 1.5 points or more; a positive change of 1.0 points or more but fewer than 1.5 points; a positive change of less than 1.0 points; a negative change of less than 1.5 points; and a negative change of 1.5 points or more. Subsequently, we calculated the percentage of students in each school that fell into the specified categories.

Finally, the change in the results of the questionnaire was calculated by subtracting the values of the fourth grade from that of the sixth grade for the year. Using the names (School 1, School 2) assigned according to the change in deviation value, the schools were rearranged in descending order. The results are shown in Figure 2.

Deviation value rank	Latent value rank	Survey response ranking
School1	School3	School29
School2	School1	School10
School3	School2	School14
School4	School6	School20
School5	School29	School24
School6	School9	School19
School7	School4	School9
School8	School21	School15
School9	School7	School38
School10	School15	School8
School11	School8	School21
School12	School5	School3
School13	School16	School28
School14	School30	School5
School15	School10	School18
School16	School24	School22
School17	School12	School34
School18	School32	School12
School19	School33	School16
School20	School18	School1
School21	School19	School40
School22	School25	School13
School23	School17	School11
School24	School13	School31
School25	School26	School41
School26	School35	School35
School27	School22	School32
School28	School14	School39
School29	School27	School4
School30	School23	School36
School31	School31	School2
School32	School39	School42
School33	School28	School25
School34	School20	School17
School35	School40	School6
School36	School36	School27
School37	School11	School23
School38	School18	School37
School39	School34	School26
School40	School41	School33
School41	School37	School43
School42	School42	School7
School43	School43	School30

Figure 2 The order of schools that produced good results and good student evaluations

School 1 ranked the highest in terms of both the deviation value and latent rank change ratios. However, in terms of change in the students' questionnaire scores, the school was in the twentieth position. These results indicate that the school had a large number of students whose abilities have improved or who were naturally able. The results could also be interpreted to indicate that the school has several students who do not have a positive opinion of the city's program.

Our focus in this study was as follows: 1) the actual increase in test results and transformation in the attitude of students toward the program (positive transformation of awareness), and identification of schools that met both these criteria; 2) division of the forty-three schools into three categories (14 upper, 14 mid-ranked, and 15 lower) and identification of schools in each category that have introduced interesting initiatives related to the three values. Therefore, to fulfill the objectives of the study, we have elaborated on the initiatives implemented by the schools highlighted in yellow in Figure 2.

Out of the forty-three schools, School 9 features in the upper category for changes seen in all three values. School 14 is the lowest of the middle-ranked schools in terms of changes in the latent rank value, but it is in the upper category for change in the other values. In other words, the school's latent rank is not high, although with the efforts of staff and students, the test scores have risen, and this is considered a positive outcome by the students. School 19 ranks in the middle in terms of change in deviation and latent rank values and ranks sixth in the upper category in terms of change in students' perceptions regarding the program, indicating that the school has been actively educating students about the benefits. School 35 has poor results in terms of the change in deviation value and is in the lower category. However, it is ranked in the middle in terms of the change in latent rank and in the students' perceptions of the program. Therefore, it has been identified as a school where the program could have an impact in the future.

Finally, School 25, which was identified based on a slightly different criteria, is ranked in the middle in terms of changes in deviation and latent rank values. Simultaneously, the change in the students' perceptions of the program is in the lower category, which implies that the program has not been received positively at the school. We decided to include this school in the focus list as the information garnered could be helpful for other schools in the same category to determine if this perception is based on the initiatives in these schools and the efforts that are being made to address this issue.

Discussion

In School 9, two initiatives were identified through teacher interviews. The first notable initiative developed at the school was the analysis of test questions by the whole teaching body to ascertain the abilities required for each unit and the utilization of that information for developing teaching methodologies and strategies. The main aim of this analysis was not to teach students the test strategies but to enable teachers to create questions that test the abilities required for the unit. The information was also utilized while questioning the students and creating the teaching material. It was also observed that teacher training was conducted across the school to support this initiative. The second notable initiative was the importance placed on making the children visualize their thought process. Teachers tried to teach the students to take careful notes and think pictorially and attempted to utilize these processes while conducting lessons based on individual optimization and in the development and utilization of relevant teaching resources. It was found that such efforts boosted the latent rank value, particularly for children at all levels (Figure 3).

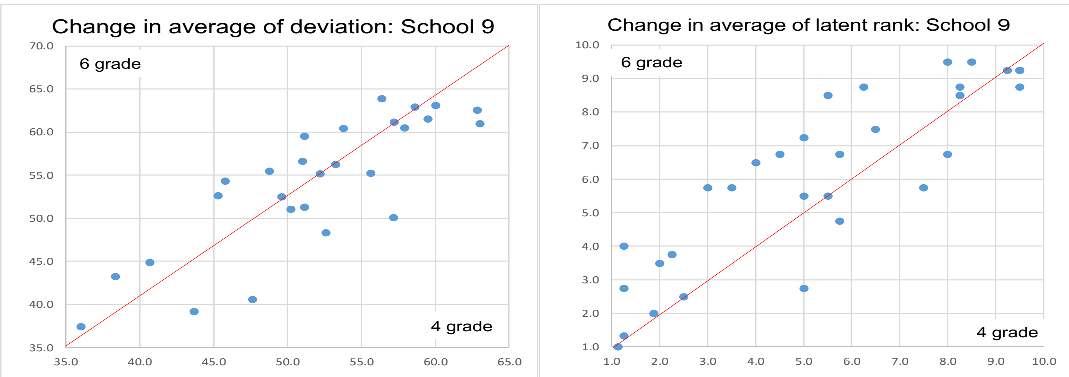

Figure 3. Changes in children's learning status in School 9

In School 14, two relevant initiatives were also identified through teacher interviews. The first was the definite use of the individual record card while planning lessons. In the cases of children whose abilities the teachers were concerned about, they carefully referred to information on the record card and used individualized methods based on the data to dispel the student's fear of arithmetic, raise awareness about their issues, and enhance their confidence. The second initiative was that students were given time during lessons to work on their individual "recommendation sheets" (with revision questions covering areas of difficulty for each individual child). The school encouraged students to independently review the learning process, ensuring that they first have time to tackle their "recommendation sheets" on their own and to work with other children on questions that they do not understand, before allowing them to read the comments. Another helpful "trick" was displaying the concepts that they had learnt previously prominently within the classroom. The children could refer to these at any time and could hence avoid mistakes that were likely to arise based on these concepts. A fourth- and fifth-grade teacher was interviewed, and the data collected for the class indicated a rise in deviation value for students with low academic performance and an overall rise in latent rank value (Figure 4).

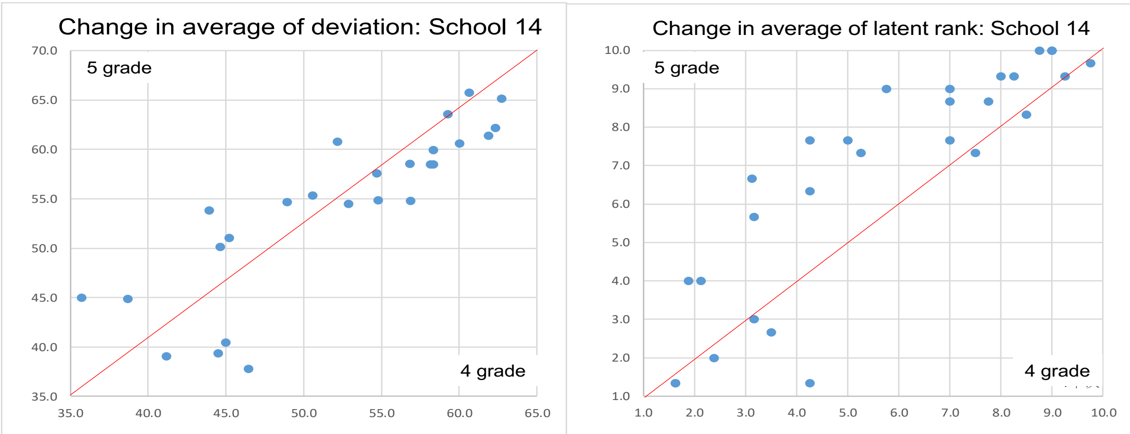

Figure 4. Changes in children's learning status in School 14

In School 19, two relevant initiatives were also identified through teacher interviews. The first was the emphasis on creating learning habits and the conscious creation of a culture of learning within the class. The school decided to share details regarding the program with the children and made them aware of the reason for and significance of using "recommendation sheets" in class and in independent study, as well as the fact that utilizing the city's system would help them understand their "own current strengths and weaknesses." The second initiative was ascertaining the support that would be effective for each student and for students who faced similar issues. Based on this information, the teachers' support was classified, and systematic attempts were made at continuous improvement.

It was found that these initiatives boosted the overall deviation value, and there was a significant rise in the latent rank value of students in the middle and lower categories (Figure 5).

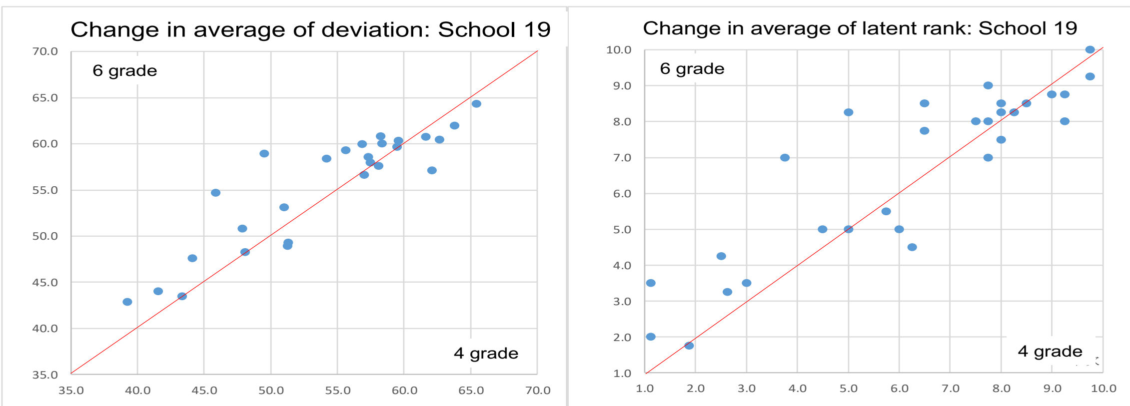

Figure 5. Changes in children's learning status in School 19

In School 35, two relevant characteristic initiatives were identified through teacher interviews. The first was ascertaining each student's learning style, thereby resulting in an improvement in the quality of teaching.

Teachers considered optimization to be not limited to individual learning. During teaching sessions, while using "recommendation sheets," they allowed students to choose whether to work in pairs and groups or to work on their own. Students with lower abilities, in particular, found it daunting to tackle the "recommendation sheets" on their own, even though they had the targeted practice questions. The attitude and behavior of the students indicated the effectiveness of working together and encouraging each other, and it was identified that this had a positive impact on teaching. The second initiative was educational guidance that consciously involved metacognition to encourage the monitoring of one's own issues and of barriers to continued learning and promoted awareness of how to adapt one's own behavior to improve the situation. A slight negative change in deviation value and latent rank value could be seen for the higher- and lower-ranked students, while minimal changes were reflected in the middle-level students. However, based on the results of the student questionnaire, it was evident that as the semester progressed, the students were more engaged in learning, implying that there is potential for improvement (Figure 6).

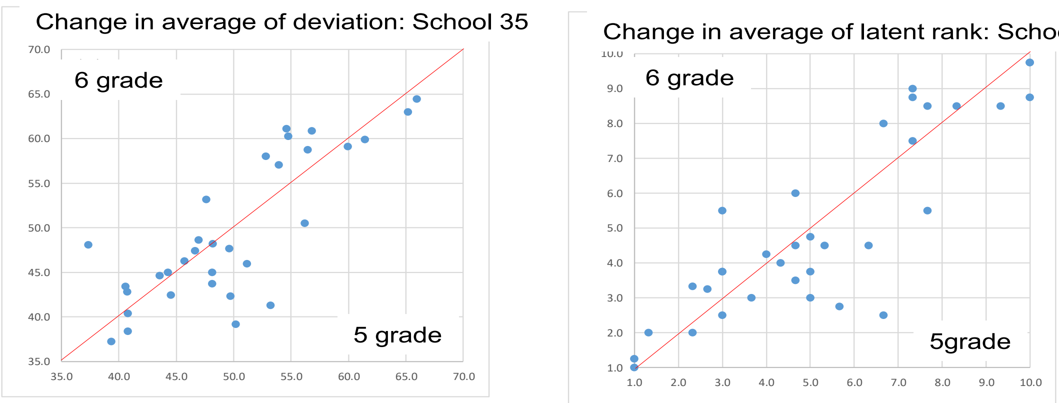

Figure 6. Changes in children's learning status in School 35

In School 25, two relevant initiatives were identified through teacher interviews. The first was that emphasis was laid on "securing and improving the areas where the students are strong," using data from the record cards to maximize the impact. The second was the analysis of the connection between the student's latent rank for each unit and the awareness of the parent or caregiver about this. Teachers believed that there is a connection between the anxiety about a particular unit with a certain latent rank and the unease felt by the parent or caregiver related to the unit. They attempted to analyze the connection between the two and tried to eliminate the miscommunication between the student and the caregiver with regard to unease and relevant initiatives. For example, a caregiver's feelings about tests can make it difficult for students to look at their test scores, identify incorrect answers, and address the relevant issues. To address this, an attempt had to be made to change the attitude toward tests on the part of both the student and the caregiver. It was found that long-term persuasive initiatives were implemented to address this. Overall, a change in the deviation value and the latent rank value can be seen. It was also identified that the perception of the students regarding the program was not very positive, as it took time to educate them about the significance of the tests and "recommendation sheets" in teaching (Figure 7).

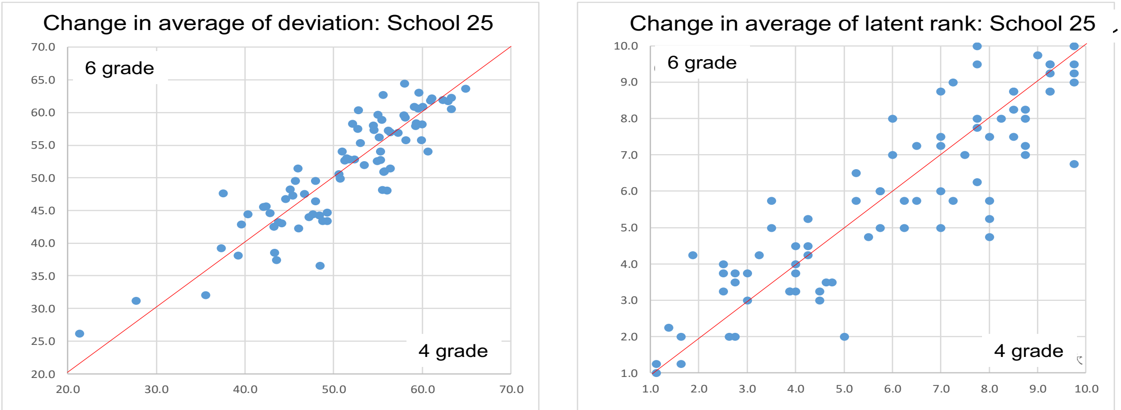

Figure 7. Changes in children's learning status in School 25

In summary, it was found that schools that were successful in using this system or made an effort to use the system in a creative way to meet the needs of the student and the local situation were doing the following five things. 1) Utilizing the information of this system in the analysis of examples and teaching materials used in the class, 2) visualizing the thinking process in the student and making it correspond to the results returned by the system; 3) making time for the child to read and understand the recommendation information returned to them by the system in class, 4) making use of an individual student's learning style in teaching, and 5) using information from this system in discussions with parents.

These findings are, in a sense, a concrete manifestation and response of the teachers to the challenge of "it remains an open question" as posed in the study by Konert, Richter, Mehm, Gobel, Bruder, & Steinmetz (2012) that we mentioned in the Introduction. We suggest that "teachers' VPMs to communicate to students," which was the concern of Symes and Putwain (2016) in the Introduction, is related to the type of instructional situation.

Reflection

As mentioned above, practical research into the use of this system was designed to guide young teachers to use the data to reconsider lessons that suit the learners, and to allow the students to grasp their own learning situation in a unit of learning. Therefore, teachers were required to embed in the lesson the time for the learners to grasp their own task from the unit test and the results of the test and to make an effort to improve. This is related to ensuring that teachers have the opportunity to think about what adaptive learning programs are and how they can be used, as described in Smith's (2018) study in the Introduction.

In June 2017, the board of education in City A explained the purpose of this initiative and co-operation towards it to the principals of all elementary schools in the city. That year, the board of education gathered teachers in charge of schools that modeled the use of this data, conducted training on data use, and created many opportunities for the exchange of opinions. In August of the same year, the board of education gathered teachers in charge of all schools in City A, which made model efforts regarding this data use, explained the purpose of this effort, requested the practice in schools, and created an opportunity to discuss this. The teachers in charge of the schools showed understanding, but some teachers were reluctant to promote it, while others showed resistance to this initiative.

The board of education also worked with the teachers in charge of the five model schools to clarify effective methods and cases of data utilization. A year later, the board of education gathered the principals of all the schools in the city and the teachers in charge of this initiative and demonstrated an effective case, calling for the promotion of practical research. The board of education also held a large educational seminar, invited citizens, and held briefing sessions with all teachers and parents about the purpose of this initiative as well as its success stories.

This effort has changed the situation. The active participation of entire schools in this effort did not increase significantly. However, the number of teachers interested in improving lessons using data has increased.

Speaking of the efforts of City A in "ways in the social cohesion/social regulation matrix" (Malin, Brown, Ion, et al. 2020), there was a shift from "the fatalist way" to "the egalitarian way" or "the individualist way." The board of education in City B was hesitant to proceed with "the hierarchist way" because this effort could require significant changes in the way individual teachers proceeded with their lessons. It was expected that if teachers were forced to proceed, it would likely fail. This was because it was thought that negotiations with the teachers' union would become a barrier if the voices of teachers who opposed this initiative increased. Therefore, although it was a city-wide policy, they chose the gradual "hierarchist way" and proceeded in a way that looked like "the fatalist way." This choice was successful and gradually increased the number of teachers, schools, and parents who were interested in using data to improve lessons (Rickinson, de Bruin, Walsh, & Hall 2017).

In the successful model, principals and lead teachers tried to relate evidence-based practice and evidence-informed practice well and tried to think about the meaning and method of using data together with other teachers. Teachers have come to think of "assessment of learning" as "assessment for learning" when it comes to data usage and began to associate it with improving the assessment literacy of teachers and their students. The teachers and schools in City A have used evidence-informed teaching practice to show teachers in other schools their creative efforts. In other words, they conducted evidence-informed teaching practice while being conscious that they would receive comments from other schools and create lessons with each other in order to generate ideas for better practice, rather than being conscious of verifying the effects (Brown,Schildkamp, & Hubers 2017, Nelson & Campbell 2017).

Acknowledgment

This work was supported by JSPS KAKENHI Grant Number JP19K03031.

References

Brown, C.,Schildkamp,K., & Hubers,M.D. (2017). Combining the best of two worlds: a conceptual proposal for evidence-informed school improvement, Educational Research, 59(2), 154-172.

Dziuban, C., Howlin, C., Moskal, P., Johnson, C., Parker, L., & Campbell, M. (2018). Adaptive learning: A stabilizing influence across disciplines and universities. Online Learning, 22(3), 7-39.

Hariyanto, D., Triyono, M. B., & Köhler, T. (2020). Usability evaluation of personalized adaptive e-learning system using USE questionnaire. Knowledge Management & E-Learning, 12(1), 85–105.

Johnson, L., Adams Becker, S., Estrada, V., and Freeman, A. (2015). NMC Horizon Report: 2015 K-12 Edition. Austin, Texas: The New Media Consortium.

Konert, J., Richter, K., Mehm, F., Gobel, S., Bruder, R., and Steinmetz, R.(2012). PEDALE--A peer education diagnostic and learning environment. Educational Technology & Society, 15(4) ,27-38.

Malin, J.R., Brown, C., Ion, G. et al. (2020). World-wide barriers and enablers to achieving evidence-informed practice in education: what can be learnt from Spain, England, the United States, and Germany?. Humanit Soc Sci Commun 7, 99. https://doi.org/10.1057/s41599-020-00587-8

Mavroudi, A., Giannakos, M., & Krogstie, J. (2017). Supporting adaptive learning pathways through the use of learning

analytics: Developments, challenges and future opportunities. Interactive Learning Environments, 26(2), 1996–2010. https://doi.org/10.1080/10494820.2017.1292531

Moltudal, S., et al. (2020). Glimpses into real-life introduction of adaptive learning technology: A mixed methods research approach to personalised pupil learning. Designs for Learning, 12(1), 13–28. DOI: https://doi.org/10.16993/dfl.138

Nelson, J., & Campbell, C. (2017) .Evidence-informed practice in education: meanings and applications, Educational Research, 59(2), 127-135.

Nuri, K.,& Nese, S.(2013). Adaptive learning systems: Beyond teaching machines. Contemporary Educational Technology, 4(2), 108-120.

Reckase, M. D. (2009). Multidimensional Item Response Theory. (pp. 179-231) New York, NY: Springer New York.

Rickinson,M., de Bruin, K., Walsh, L., & Hall,M. (2017). What can evidence-use in practice learn from evidence-use in policy?, Educational Research, 59(2), 173-189.

Shojima, K. (2007). Latent rank theory: Estimation of item reference profile by marginal maximum likelihood method with EM algorithm. DNC Research Note, 07-12. http://www.rd.dnc.ac.jp/~shojima/ntt/index.htm

Smith, K. (2018).Perceptions of preservice teachers about adaptive learning programs in K-8 mathematics education. Contemporary Educational Technology, 9(2), 111-130.

Symes, W. and Putwain, D. W. (2016). The role of attainment value, academic self-efficacy, and message frame in the appraisal of value-promoting messages. British Journal of Educational Psychology, 86(3), 446-460.

Walkington, C. A. (2013). Using adaptive learning technologies to personalize instruction to student interests: The impact of relevant contexts on performance and learning outcomes. Journal of Educational Psychology, 105(4), 932–945. https://doi.org/10.1037/a0031882