

RESEARCH ARTICLE

A Qualitative Case Study on the Implementation of an AI-Powered Gait Rehabilitation Robot Program for Students with Severe and Multiple Disabilities

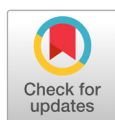
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ABSTRACT

This qualitative case study explored how an AI-powered gait rehabilitation robot program was implemented over one semester in a special school and how its participants experienced and made sense of it. The bounded case was the program itself; its participants comprised three students with severe and multiple disabilities, the teacher-researcher (a special education teacher), a collaborating physical therapist, and three guardians. Data were collected from multiple sources, including health-management records and assessment sheets, class documents and Individualized Education Program (IEP) team minutes, robot-recorded gait data, semi-structured surveys and interviews, participant-observation logs, and the researcher's reflexive journal. The data were analyzed through iterative coding, pattern identification, and cross-source comparison, with attention to discrepant data, and trustworthiness was strengthened through triangulation, member checking, and peer debriefing. Three themes were identified. First, the program was implemented within a co-teaching model that connected the special education teacher and the physical therapist across the boundary of education and therapy, and it was organized as a related service through IEP team consultation under the 2022 revised special education curriculum. Second, the participants moved from initial expectation and concern toward a more nuanced appreciation of the program, while also raising practical concerns about safety, sensor limitations, and the burden of responsibility. Third, the students showed uneven but meaningful changes. Although gains on the ordinal functional indicators (MMT, BBS, FAC) were partial or limited to maintenance, clearer changes appeared in confidence, self-efficacy, and social participation. Rather than verifying effectiveness, this case illustrates the possibilities and conditions of school-based AI gait-robot education and points to the need for a sustainable policy and institutional support framework, including the placement of rehabilitation professionals within schools.

Keywords: Students with severe and multiple disabilities, AI gait rehabilitation robot, gait education, qualitative case study, co-teaching



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Introduction

Advances in science and technology have been applied to rehabilitation and special education, helping to ease the constraints on the lives of people with disabilities and to improve their quality of life. In particular, artificial intelligence (AI) and robotic technologies are attracting attention in education as instructional media and learning tools that support teachers' instruction, and in rehabilitation as tools that reduce therapists' physical burden while delivering precise and consistent interventions (Chang & Chun, 2015; Kang et al., 2013). Students with severe and multiple disabilities have two or more disabilities of such severity that they require intensive and comprehensive support across cognition, motor function, sensation, behavior, communication, and daily living, and they have highly individualized and comprehensive educational needs regardless of chronological age or grade (Han et al., 2019). For these students, improving physical activity and walking ability is a life-function task essential to survival and independence as well as a core educational goal that expands opportunities for participation in daily life and exploration of the environment (Han, 2020). Reflecting these needs, the 2022 revised Basic Curriculum for Special Education newly established the daily living activities area and included physical activity within it, thereby providing a basis for implementing a functional curriculum for students with severe disabilities (Song et al., 2024).

Special education practice faces problems such as the absence of an agreed conceptual definition of severe and multiple disabilities and the gap between curriculum content and student characteristics, and above all, the dilemma over the boundary between rehabilitation therapy and education has been raised continually (Kim, 2025). As rehabilitation training and health management to improve physical disabilities have become essential areas in the education of students with multiple and physical disabilities, special education teachers experience conflict over whether the rehabilitative approaches they carry out constitute educational acts (Kim, 2025). Moreover, although many students with severe and multiple disabilities require medical support, regulations on the placement of professional personnel in schools, legal protection in emergency situations, and the scope and targets of medical support remain inadequate (Ahn et al., 2024; Baek et al., 2023). In this situation, linkage and collaboration between special education teachers and related professionals such as physical therapists, together with the teacher expertise and support competencies that underpin such collaboration, are strongly emphasized (Kim & Song, 2022; Park et al., 2022).

An AI gait rehabilitation robot is an advanced assistive technology device that combines AI technology with a rehabilitation robot and is used to enhance walking function (Moon & Cho, 2021). The device operates as a torque-assisted wearable exoskeleton that detects the user's residual muscle strength and movement intention through sensors and provides only as much assistance as needed; it processes sensory data in real time to intelligently adjust the intensity and speed of assistance and provides individualized training (Moon & Cho, 2021). Robot-assisted gait training makes it possible to perform, within a single session, the high-intensity repetitive movements required to induce neuroplasticity, and thus can realize the task-oriented and high-intensity training principles recommended in international clinical guidelines for gait rehabilitation (Calabrò et al., 2021; Homby et al., 2020). Indeed, improvements in walking function through robot-assisted rehabilitation have been reported for patients with neurological injuries such as stroke, spinal cord injury, and cerebral palsy (Chang & Chun, 2015; Kim et al., 2025). More recently, studies have reported that overground gait training with wearable robots brings significant improvements in gross motor function and gait in children with

cerebral palsy (Choi et al., 2024; Hong et al., 2022; Kim et al., 2021; Yoo et al., 2021), and in adult patients with neurological disorders, improvements in muscle strength, balance (BBS), and Functional Ambulation Category (FAC) have been reported together with an adaptation period of about six sessions and mild adverse events (Park et al., 2023). Nevertheless, meta-analyses and systematic reviews of overground gait training judge the clinical evidence to be still at an early stage (Conner et al., 2022; Sarajchi et al., 2021).

However, most prior findings were produced with adult stroke patients (Park et al., 2021) or in the clinical settings of hospitals and rehabilitation centers or under clinical trial conditions (Choi et al., 2024; Chang & Chun, 2015), and research on how an AI gait rehabilitation robot is operated within the school curriculum for school-age students with severe and multiple disabilities is very scarce. Furthermore, existing research on robot-assisted rehabilitation has generally focused on quantitatively verifying effectiveness (Song et al., 2012; Song et al., 2016), and qualitative studies that explore in depth the actual process of educational implementation and the experiences and perceptions of the teachers, therapists, and guardians who take part in it have hardly been conducted (Park et al., 2021). In addition, most studies remain confined to the perspective of a single professional (a physical therapist or a teacher) (Song et al., 2012), so empirical understanding of collaborative models in school settings where education and therapy are combined is insufficient.

Internationally, too, school-based rehabilitation services have been shifting from a mode in which therapists treat students separately toward models in which therapists collaborate with teachers and support students within the educational context (Campbell et al., 2023; Jeremy et al., 2025); the adoption of wearable robots in practice depends on therapists' acceptance of the technology and on facilitating conditions such as personnel and time (Herold et al., 2024; Olimb Hillkirk et al., 2025); and in outcome measurement, a perspective that regards participation as both a process and an outcome of intervention is emphasized (Imms et al., 2017). Studies that examine a case in which an AI gait rehabilitation robot was operated within the curriculum of a special school in connection with these discussions, however, remain scarce.

The purpose of this study is to qualitatively explore, in a bounded case of AI gait rehabilitation robot education operated at one special school, how the education was implemented within the school curriculum and the Individualized Education Program (IEP), and how the students, special education teacher, physical therapist, and guardians who took part in this process experienced and perceived it. The research questions established to achieve this purpose are as follows.

First, how was AI gait rehabilitation robot education for students with severe and multiple disabilities concretely implemented within the school curriculum and the IEP in a special school setting?

Second, how did the special education teacher, physical therapist, and guardians who took part in this education experience and perceive its implementation?

Third, what changes appeared in the participating students through AI gait rehabilitation robot education?

Research Methods

Research Design

This study applied the qualitative case study method, which is suited to exploring how and why a phenomenon occurs within its real-life context without the researcher controlling the phenomenon (Yin, 2018). The reasons for conducting a qualitative case study are as follows. First, AI gait rehabilitation robot education is an early-stage phenomenon that has only just been introduced to special education settings, so a process-oriented exploration of how it is implemented, what difficulties and possibilities it entails, and how participants receive it is more appropriate than an outcome-oriented question of how effective it is (Brantlinger et al., 2005; Merriam & Tisdell, 2016). Second, because students with severe and multiple disabilities are highly individual and heterogeneous, an in-depth understanding of a small number of cases is required in order to capture the small changes, nonverbal responses, and interactions that are difficult to analyze with standardized scales alone (Merriam & Tisdell, 2016).

In this study, the case is a bounded system, namely the AI gait rehabilitation robot education program operated for one semester at one special school. The students, special education teacher, physical therapist, and guardians were not set up as independent research subjects but as constituent elements of the case who jointly constructed the program and interacted within it; accordingly, their experiences and perceptions are treated as multiple perspectives for understanding the program within the boundary of the case. Although case studies are classified in various ways depending on the approach (Yazan, 2015), this study adopted a single case design (Yin, 2018) that combines the descriptive and interpretive approaches of Merriam and Tisdell (2016), richly describing the actual process of educational implementation and the participants' experiences and then interpreting the educational meaning they carry.

The researcher performed a dual role as the special education teacher who led the operation of the program and as the human instrument who collected and interpreted the data. This positionality carries the strength of deep understanding of the field together with the risk of bias toward positive interpretation. To control for this, the researcher kept a reflexive journal to continually examine his own expectations and interests, and sought to secure the validity of interpretations on the basis of the data by drawing together the independent evaluations of the physical therapist and guardians, the observation records of fellow teachers, and objective assessment indicators (Brantlinger et al., 2005).

Although the students are the core participants of this case, because of the limits on expression that accompany severe and multiple disabilities, their experiences were collected mainly in a form mediated by data recorded by adults, such as observation logs, health-management records, and the reports of guardians and the physical therapist. The description of the students' changes is therefore grounded in the contents and experiences recorded and interpreted by adult observers. To reduce this limitation, the students' brief utterances captured in the observation records are presented verbatim together with their dates.

Participants and Selection

The participants were composed through purposive sampling, which intentionally selects information-rich cases that fit the research purpose (Merriam & Tisdell, 2016). They consisted of the core participants at the center of the case (three students with severe and multiple disabilities) and the peripheral participants who took part in operating the program

(one collaborating physical therapist, three guardians who were each student's primary caregiver, and the researcher, the special education teacher who operated the program). Students were selected according to the following criteria: (1) a diagnosis of severe and multiple disabilities including brain lesion disorder; (2) physical conditions allowing the AI gait rehabilitation robot M20 to be worn (height 115 to 190 cm, weight 90 kg or less); (3) a level of spasticity permitting safe wearing of the robot and training (below MAS grade 2 at the time of fitting); (4) the ability to express walking intention and to communicate at a basic level; and (5) guardian consent and the ability to participate at least twice a week. These criteria were set with the physical feasibility of wearing the robot and safety during training as the foremost considerations. Five students were initially selected, but two who were unable to participate consistently for health reasons were excluded, and the three who participated steadily throughout the program were confirmed as the final participants. Written informed consent was obtained from all participants and, for the students, from their guardians, including separate consent for the academic use of anonymized photographs and video. The basic characteristics of the participating students are shown in Table 1. Although formal classification by the Gross Motor Function Classification System (GMFCS; Palisano et al., 1997) was not conducted, in view of the pre-program walking ability presented in Table 1, the gross motor function of the three students can be regarded as corresponding approximately to GMFCS Levels IV to V.

Table 1. Characteristics of the participating students

Student	Gender / Age	Grade	Primary disability	Gait ability before the program
A	Male / 9	Grade 3 (Elem.)	Brain lesion disorder: Intellectual disability(severe)	Short-distance ambulation with a walker and physical support: unable to stand or walk independently
B	Female / 18	Grade 2 (High)	Brain lesion disorder: Intellectual disability(mild)	Fully dependent on a powered wheelchair: unable to stand or walk
C	Female / 18	Grade 3 (High)	Brain lesion disorder: Intellectual disability(mild)	Wheelchair-dependent: able to stand briefly with upper-limb support

The researcher is a special education teacher who has taught students with severe and multiple disabilities in a special school and was responsible for planning and operating the program, and the collaborating physical therapist is a licensed physical therapist with three years of total clinical experience, including one year in the field of special education, who took part in the program through a memorandum of understanding (MOU) with a professional institution outside the school. The two professionals' different occupational expertise, that is, an educational approach grounded in understanding of the curriculum and the students and a clinical approach grounded in the assessment of musculoskeletal and neurological function and rehabilitation intervention, operated in a mutually complementary way in the division of roles within the co-taught lessons.

To comply with research ethics, written consent was obtained from all participants before data collection. The researcher fully explained the purpose and content of the study, the methods of data collection, the protection of personal information, and the voluntary nature of participation with the right to withdraw at any time. For the students, consent to participate was obtained from their guardians together with separate consent for the academic use of photographs and videos of educational activities; all data were anonymized, and the faces of students and other persons were de-identified so that they cannot be recognized.

The AI Gait Rehabilitation Robot Program

The program studied was operated using two wearable AI gait rehabilitation robots, M20 (small and large), introduced by the school. The robot operates as a torque-assisted exoskeleton that detects the student's residual muscle strength and movement intention through sensors and adjusts the intensity of assistance in real time, and it automatically records the total walking time, number of steps, walking distance, and average walking speed for each session. Depending on the student's functional level, a Full-assist mode in which the robot leads walking, an Assist-as-needed mode that supports the student's active movement only as much as necessary, and an autonomous walking mode in which the student leads walking were applied on an individualized basis. The special education teacher used the data produced by the robot as the basis for setting goals and monitoring progress for each student, attempting data-based individualized education in which changes that are hard to grasp through observation alone are interpreted together with objective data. The program was not organized as a separate therapeutic activity but as a special education related service through consultation with the IEP support team, and it was operated as an educational activity linked to the daily living activities and physical activity areas of the 2022 revised special education curriculum and to each student's instructional goals (e.g., strengthening lower-limb muscles and sitting and standing independently, increasing lower-limb joint range of motion, and reducing dependence on the upper limbs).

The program was operated twice a week (Mondays and Thursdays) in accordance with the physical activity education timetable, with 40 minutes per session (5 minutes of introduction, 30 minutes of development, and 5 minutes of wrap-up). During the intensive data collection period, a total of 33 sessions were actually held, excluding public holidays and the school's discretionary holiday, and the sessions attended by each student were 28 for Student A (84.8%), 32 for Student B (97.0%), and 30 for Student C (90.9%). Absences occurred for reasons such as colds, hospital visits, and field trips, and even among the sessions attended, on days when a student had a slight fever or was in poor condition, robot walking was replaced with stretching and range-of-motion exercises on the mat.

Data Collection

To gain a multifaceted and in-depth understanding of the case, data were collected through various methods over approximately four months (one semester), from March 17 to July 22, 2025. This was the intensive data collection period; since the introduction of the program in March 2024, the researcher had continuously interacted with the students and observed their changes through prolonged engagement.

The initial items of the semi-structured survey and interview instruments for the physical therapist and the guardians were constructed on the basis of the research questions and a review of prior studies. The question domains were set with reference to a study on the use of assistive technology and special education teachers' experiences of using it (Park et al., 2022), and the question domains for each participant group were specified on the basis of prior studies on physical therapists' perceptions of rehabilitation robots and guardians' perceptions of educational support. The initial items were submitted for content validity review to the academic advisor, a professor of special education, a professor of physical therapy, and a physical therapist with more than ten years of clinical experience, and the clarity, appropriateness, and redundancy of the items were revised and supplemented; a pilot test was then conducted with one special school teacher

and one guardian of a student with disabilities who were not research participants to check comprehensibility, after which the final items were confirmed.

The survey and interview instruments were composed of six domains: motivation for participation, program operation, students' responses and changes, collaboration and communication, perceptions of AI technology, and directions for development. The physical therapist's instrument included items such as "Two 40-minute sessions per week were appropriate for the students" (Likert) and "The most memorable scene in the initial, middle, and late phases of the program" (open-ended), and the guardians' instrument included items such as "The number and length of sessions were appropriate" (Likert) and "The most meaningful change observed at home, with a concrete episode" (open-ended).

Guardian interviews were conducted once each at the start of the program (March) and at its end (July), for about 30 minutes per session, in the school's AI convergence education room, and in between, changes observed at home were confirmed through telephone consultations. The physical therapist interview was conducted in July together with the survey for about 60 minutes, and interviews with the homeroom teachers (early March, late June, and July) were used to confirm changes in the classroom. Interviews were audio-recorded with the participants' consent.

The data collected fall into three types. First, survey and interview data include the semi-structured surveys and interviews with the physical therapist and guardians, the homeroom teacher interviews, and the reflective items completed by the special education teacher (the researcher). Second, documents and records include the physical activity education timetable, participation application forms, student background surveys, health management support team minutes, student health management cards and health-management records, physical activity education assessment sheets, gait rehabilitation robot education assessment sheets, class reports, IEP support team minutes, and the data automatically recorded by the AI gait rehabilitation robot. Third, participant observation records include student observation logs and photographs and videos of activities. Likert-scale responses were used only as supplementary data to confirm the direction of participants' perceptions; no item-level numerical analysis was conducted, and the results are summarized in the results section for each participant.

Data Analysis and Trustworthiness

The analysis proceeded in five stages according to the three research questions. (1) In the data organization and classification stage, all collected data were arranged in chronological order and classified by research question. (2) In the integrated review and pattern identification stage, each data source was read repeatedly at least three times, and initial coding that summarized the core content was performed. For example, the physical therapist's statement "Through the robot, they can look at their peers from a new eye level" was coded as change of perspective and social interaction, and the improvement in their children's confidence mentioned in common by the three guardians was integrated into the category of emotional growth (pattern identification). (3) In the temporal and thematic structuring stage, the implementation process was reconstructed along the temporal flow of introduction, development, and wrap-up; the participants' experiences along the flow from expectation through experience to changed perception; and the students' changes by individual case. (4) In the descriptive writing stage, objective facts and the participants' verbatim statements were presented together with contextual information. (5) In the cross-source checking stage, whether the content of one

data source was consistently confirmed in other sources and whether changes in the quantitative indicators corresponded to the qualitative observations were examined. Coding and categorization were carried out by the researcher by hand without separate software, and the categories derived were reconfirmed through peer debriefing. Data that ran counter to the program's success narrative, such as the session in which the sensors did not recognize gait (March 24, Student B) or sessions in which robot training was replaced because of poor condition, were coded separately into negative-case categories such as technical limitation and condition-based operation.

In the cross-source checking stage, not only points of agreement but also discrepancies were recorded. For example, the physical therapist stated in the interview that the students' muscle strength "improved by one grade on average on the MMT," whereas the grades recorded on the assessment sheets remained within-grade changes or maintenance; in this case, the measurements were given priority in the description and the statement was classified as perception data. Data that contradicted the success narrative, such as the reduced training volume in July owing to hot weather or a complaint of knee pain, were also included in the results as they were.

The following strategies were applied to secure the trustworthiness of the study. Through data triangulation, diverse data such as observations, surveys, and documents and the perspectives of the teacher, physical therapist, and guardians were brought together, and the prolonged engagement described above was maintained. Member checking was conducted by sharing part of the analysis results with the physical therapist and the guardians to confirm that the descriptions accurately reflected their experiences. Peer debriefing was carried out with fellow teachers specializing in special education and the academic advisor, who jointly reviewed, at the categorization and writing stages, whether the derived categories and representative quotations were grounded in the data. However, no separate codebook was developed and no inter-coder agreement was calculated. In addition, thick description of the context, background, activities, and process of change provided a basis for judging transferability, and the raw data (observation logs, assessment sheets, robot data, etc.) were kept systematically to secure confirmability (Lincoln et al., 1985; Merriam & Tisdell, 2016; Yin, 2018).

Results

Implementation of the Program within the Curriculum and IEP

Rationale, Legal Basis, and Curricular Placement

The introduction of the program was grounded in legal bases such as the Act on Special Education for Persons with Disabilities, the School Health Act, and the Act on Guarantee of Right to Health and Access to Medical Services for Persons with Disabilities, and in the establishment of the physical activity area in the 2022 revised special education curriculum. The school introduced two AI gait rehabilitation robots, M20 (small and large), in December 2023 and began actual education in March 2024, and the intensive data collection of this study took place from March to July of the following year, 2025. Rather than being a separate therapy period, the program was organized as a special education related service through consultation with the IEP support team and operated as an educational activity linked to each student's instructional goals and to the daily living activities and physical activity areas, in an attempt to deal

with the boundary between rehabilitation and education in an integrated manner within the curriculum. However, securing a separate instructional period within the existing timetable in connection with the physical education subject and registering it in the National Education Information System (NEIS) for this arrangement was an administrative procedure that required the agreement of several teachers and consultation with the research department.



Fig. 1. Class sessions in the AI healthcare room: fitting the AI gait rehabilitation robot on a student (left) and a student standing in the robot with the fall-prevention walking trainer before overground walking (right)

Co-teaching Collaboration and Role Division

The program was operated systematically through an MOU with a professional institution, the formation of a health management support team, and a co-teaching model. It was run as a two-teachers-in-one-class arrangement in which the special education teacher and the physical therapist divided their roles clearly on the basis of their respective expertise while collaborating organically: while the physical therapist was responsible for aspects of physical function such as lower-limb muscle activation, balance, and posture, the special education teacher supported the students' motivation, emotions, communication, and safety and connected the activities to educational goals. This division of roles shows that a collaborative model in which expertise is mutually complemented (Kim & Song, 2022) can be one practical response to the dilemma that special education teachers have experienced at the boundary between rehabilitation therapy and education (Kim, 2025).

Educational Environment, Content, and Procedure

The AI healthcare room on the third floor of the school was used as the main venue, and gait education was also carried out as needed in real environments such as corridors and ramps. The students were selected through consultation of the health management support team, and their conditions were diagnosed in detail through initial assessment. The explanations of the rehabilitation and functional assessment indicators, excerpted from the rehabilitation standards and terminology materials of the National Rehabilitation Center, are presented in Table 2.

Table 2. Explanation of rehabilitation and functional assessment indicators

Indicator	Description
Manual Muscle Testing (MMT)	Grades muscle strength against examiner resistance (higher = stronger)
Range of Motion (ROM)	Joint range of motion measured with a goniometer (closer to normal = better)
Modified Barthel Index (MBI)	Ten daily-activity items scored 0–100: higher = more independent basic ADL
Functional Ambulation Category (FAC)	Walking-independence grade 0–5: higher = more independent gait
Berg Balance Scale (BBS)	Balance ability scored 0–56 across 14 tasks: higher = better balance
Modified Ashworth Scale (MAS)	Muscle spasticity grade: lower = less spasticity (stiffness)

The educational content was organized with reference to the principles of high-intensity repetitive training, task-oriented gait training, and progressive adjustment of difficulty recommended in international clinical guidelines for gait rehabilitation (Calabrò et al., 2021; Hornby et al., 2020). The Full-assist, Assist-as-needed, and autonomous walking modes of the AI gait rehabilitation robot M20 were applied to each student on an individualized basis, and the lessons were scheduled twice a week (Mondays and Thursdays) at 40 minutes per session, with each session consisting of introduction (5 minutes), development (30 minutes), and wrap-up (5 minutes). In the introduction stage, greetings were exchanged and goals were confirmed; in the development stage, warm-up exercises, AI gait rehabilitation robot education, and cool-down exercises were carried out; and in the wrap-up stage, results were reviewed and impressions were shared. Table 3 presents excerpts of each student's training records, as documented in the student health-management records, the quarterly class reports, and the monthly summaries of robot data, together with the actual dates in the initial, middle, and late phases of the program.

Table 3. Documented gait-training records of the three students by phase

Student	Initial phase	Middle phase	Late phase	Assist level
A	Mar 24: fearful at the first fitting; about 5 m of walking in Full-assist mode (March average about 5 min, 150 steps per session)	Apr 14: stairs from the 3rd-floor healthcare room to the 2nd-floor classroom, about 150 steps; May 12: 3rd to 4th floor round trip, about 500 steps	Jun 16: walker walking without the robot began; July average 20 min or more, about 900 steps per session	15, 13, 11, 9
B	Mar 17: about 5 min of standing in the robot; Mar 24: sensors did not recognize gait because of knee flexion contracture	Apr 14: 80 m in stair-walking mode; May: about 160 m	Jun 5: about 160 m in 17 min with two rests; July: distance decreased on hot days	15 to 12 (target)
C	Mar: about 150 steps in flat-walking mode (March average about 8 min, 200 steps per session)	Apr: about 200 steps in stair-walking mode; May 8: ramp walking about 220 m in 20 min with two rests	Jun: 60 m of walker walking in the walking suit; July average about 20 min, 750 steps or more; Jul 14: walker walking without the robot, 5 m in 3 min	14 to 10

Records are quoted from the dated health-management records, class reports, and monthly summaries of robot data; increases reflect both functional change and the planned increase in training volume. For Student B, knee flexion contractures prevented the sensors from recognizing a normal gait cycle, so B's entries rely on the therapist's and teacher's records. Assist level ranges from 0 to 20 (higher = more assistance).

The figures in Table 3, however, must be interpreted with several limitations in mind. First, increases in walking time and distance may reflect not only improvements in the students' function but also increases in the training volume itself (lesson time and target walking amount) as the sessions progressed, so gains in ability and changes in training volume are intermingled. Second, for Student B, severe contractures of both knee joints prevented the robot's sensors from recognizing gait reliably, which limited the collection of quantitative data; interpretation based on robot data was therefore centered on Students A and C, for whom data collection was relatively stable. The records for Student B are based on the physical therapist's visual observation and the teacher's records. Third, in July there were sessions in which training time and walking distance were shorter than usual because of hot weather. These data were treated as descriptive reference material showing the progression of training rather than as a precise measurement of effects.

Participants' Experiences and Perceptions of the Program

With regard to the second research question, the three peripheral participants of the program (the special education teacher, the physical therapist, and the guardians) started from initial expectations and concerns and reconstructed their perceptions as they witnessed the students' changes together, but tensions and limitations that cannot be reduced to a success story also emerged in that process.

The Special Education Teacher (Researcher)

Regarding the purpose of the introduction, the researcher stated, "I expected that introducing advanced AI assistive technology into special education would compensate for the students' disabilities and raise their educational achievement," but in actual implementation he pointed to "safety issues during the program, the selection of participating students, and equipment maintenance and management, in addition to whether it could be operated stably" as major concerns. There was also the administrative difficulty of securing a separate instructional period within the existing timetable; the researcher stated that he "worked out a practical operating plan through in-depth consultation with the research department," revealing that considerable coordination and difficulty accompanied the process of settling a new technology into the curriculum.

In the collaborative process as well, there was trial and error in communication and operation at first because of the difference in the professional domains of the special education teacher and the physical therapist. The researcher recalled, "There were difficulties arising from differences in our fields of expertise and perspectives, but the two professionals' perspectives merged naturally, and I felt great pride and reward in the process of creating synergy together." In particular, the case of a student who had used only a wheelchair all her life complaining of knee pain during training brought home how important physical safety and professional management are in applying advanced assistive technology in schools. The researcher stated that this experience made him "clearly recognize the need to continually check and guide the student's health condition in linkage with a medical institution." This reflection suggests that gait intervention in schools must take place not merely with proficiency in operating the equipment but within institutional safeguards that support cooperation with medical networks and multidisciplinary collaboration.

Among the reflective items, the only one to which the researcher did not respond positively was "My teaching

competence in using advanced technology has improved,” because the growth did not go beyond learning how to operate the robot and, rather, he “came to clearly recognize the limitation that, without professional knowledge such as physical therapy, a special education teacher alone cannot respond appropriately to a student’s unexpected situations.” The case in which a student cried and refused during training, and the special education teacher, who knew the student’s personality and home environment, mediated and brought the lesson to a close, became an occasion that confirmed the need for collaboration for both professionals.

The Collaborating Physical Therapist

The physical therapist took part with the motivation that she “wanted to see what changes would occur if the AI gait rehabilitation robot were applied to special school students, and wanted to be of help, even if only through short lessons, in the environment where the students live their lives.” In the initial phase (March), the students had difficulty adapting to the robot, but the physical therapist noted that “the students who use wheelchairs were being motivated as they positively experienced being able to look at their peers from a new eye level through the robot,” and confirmed psychological and emotional changes. In the middle phase (April to May), participation increased as the students adapted to the device, and in the late phase (June to July), functional changes were recorded, such as “a student who had previously found walker walking difficult was observed for the first time pushing the walker and walking on her own.” The physical therapist evaluated that she “could really feel that robot therapy is not limited to changes inside the treatment room but also has a positive effect on improving daily living functions at school and at home.” The physical therapist responded “strongly agree” to all of the items concerning collaboration with the special education teacher (communication, the distinction and mutual respect of expertise, improvement in the quality of education, and joint responses to problem situations).

The physical therapist also revealed critical reflection on the technology. Before participating, she had “a concern that the AI gait rehabilitation robot might replace the role of therapists and reduce jobs,” but after applying it in the field she said she had come to perceive the robot not as a substitute but as a tool that expands professional competence. This shift was intertwined with the experience of witnessing students standing in the robot and gaining motivation as they looked at their peers from a new eye level, the change in which Student C came to walk pushing a walker without the robot, and the experience of situations that the robot alone could not resolve, such as a student crying and refusing or the robot’s sensors failing to recognize gait. Nevertheless, she made clear that fine adjustments according to individual characteristics such as the student’s muscle strength and body shape still “require the therapist’s professional judgment and intervention,” and with regard to safety accidents she confided that “the risk is too great for a physical therapist to bear alone.” This underscores that an institutional safety system that relieves practitioners’ psychological and physical burden must precede the settling of advanced technology into practice (Ahn et al., 2024; Baek et al., 2023).

The Guardians

The guardians decided to participate in the hope that their children’s physical function would improve, even if only in the short term, and their expectations differed according to their children’s conditions. Student A’s guardian expressed a hope for functional improvement, “wondering whether [my child]’s walking might get even a little better”; Student B’s guardian expressed a practical expectation, “wondering whether she might at least be able to practice standing”;

and Student C's guardian expressed a perspective of future adaptation, that "experiencing and adapting to this kind of advanced technology in advance will help her in life ahead." After the program, the guardians described changes at home concretely: Student A's guardian reported that "now [my child] has changed to the point that he is the first to suggest pushing the walker to the parking lot," and Student B's guardian reported that "now she practices dozens of times trying to get up and sit on the bed by herself."

All three guardians responded "agree" or "strongly agree" to the items on program operation, such as the number of sessions, the length of sessions, safety management, the teachers' guidance, and the provision of information, and responded negatively when asked whether their children had complained of fatigue or discomfort after the sessions to a degree that interfered with daily life. The guardians cited the teachers' attentive guidance, which flexibly adjusted the training intensity according to the child's condition on the day, as the basis of their trust. Student C's guardian, who had worried about safety because of her daughter's lack of sensation in the lower limbs, stated, "I could feel at ease because the teacher carefully checked her condition every time, asked whether she was in pain, and adjusted the intensity." This shows that, more than the introduction of advanced technology itself, the teacher's active mediation and emotional rapport that take the student's characteristics into account are the key conditions for relieving guardians' anxiety and guaranteeing a stable educational environment. The initial vague expectations or skepticism shifted, once the guardians confirmed their children's changes, toward a perception of AI technology as a tool that opens up their children's possibilities. This change in the participants' perceptions is also in line with prior research indicating that the perceived usefulness and ease of use of a technology are important for its acceptance (Park et al., 2022).

Changes in the Participating Students

With regard to the third research question, the results of the rehabilitation and functional assessments conducted before and after the program are shown in Table 4. Because MMT and FAC are ordinal scales, it is inappropriate to summarize their grade values by arithmetic averaging, so each student's changes are described individually. Improvement of the same magnitude did not appear in all three students; changes in the quantitative indicators were limited to partial improvement or maintenance, whereas more marked changes were observed in emotional and social dimensions such as confidence, self-efficacy, and social participation. There was a discrepancy between data sources here. In the July interview the physical therapist stated that "muscle strength improved by one grade on average on the MMT," but the grades recorded on the assessment sheets, as shown in Table 4, remained within-grade changes or maintenance. This study gave priority to the measurements in its description while interpreting this difference as data showing that the changes the physical therapist perceived in her session-by-session observations were of a magnitude difficult to reflect in the intervals of the grading scale.

Table 4. Changes in students' MMT, BBS, and FAC scores before and after the program

Student	Assessment item	Pre(Mar)	Post(Jul)	Change
A	MMT (Hip flexion, Rt)	F-G	G	Within-grade gain
A	BBS (total)	10	11	+1 point
A	FAC	Level 2	Level 2	Maintained
B	MMT (Hip flexion, Rt)	F-F+	F+	Maintained (within the initially recorded range)
B	BBS (total)	7	7	Maintained
B	FAC	Level 1	Level 1	Maintained
C	MMT (Hip flexion, Rt)	F	F+	Within-grade gain
C	BBS (total)	9	9	Maintained
C	FAC	Level 1	Level 2	+1 level

MMT was graded for right hip flexion. A hyphenated entry (e.g., F-G, F-F+) indicates that the therapist recorded the strength as lying between the two adjacent grades. Because MMT and FAC are ordinal scales, changes are described for each student and are not averaged.

Student A: Growing Confidence in Doing Things Independently

Before the program, Student A was restricted in standing and walking independently, showed a tendency to avoid activities, and displayed fear in the early days of the robot's introduction. The health-management record of March 24 states, "Showed fear when the AI gait rehabilitation robot was put on and said 'I'm scared'..." The physical therapist reassured him, saying "The robot is helping you, [name], and I'll be right beside you," and set the assistance level high so that the robot led the movement," showing that acceptance of the technology was not entirely smooth. This initial resistance eased through successful experiences and mediation, and two weeks later, on April 7, a change was observed: "Asked to put on the robot himself. Showed an active attitude, saying 'I want to go outside.'"

There were also days that did not go smoothly. On April 21, because of a slight fever, robot training was replaced with stretching on the mat, and when the student said "I want to rest," his wish was respected. On May 12, by contrast, the record states, "Completed a round trip between the third and fourth floors. Reached a total of 500 steps. The robot's assistance level was lowered from 13 to 11. Student A completed the session to the end, saying 'I can do it,'" and on June 16, when people around him praised him as they saw him walking with a walker without the robot, he replied, "I worked hard."

On the clinical indicators, the Berg Balance Scale (BBS) improved from 10 to 11 points and hip flexion muscle strength (MMT) from F-G to G, and in the July assessment the physical therapist recorded that "the duration of continuous walking with the walker increased from about 2 minutes to more than 5 minutes" and that "he was also observed walking about 10 steps while maintaining balance holding both hands, without the walker." In the final interview, the guardian described her son transferring to his wheelchair by himself and said, "At that moment I really almost cried." What stood out in Student A's case was not the size of the numbers but the process in which the emotional conviction that "I can do it" changed his attitude from avoiding activities to attempting them voluntarily.

Student B: From Withdrawal to Regained Smiles amid Limited Quantitative Change

Student B was entirely unable to stand or walk independently and relied on a powered wheelchair for all mobility; she was emotionally withdrawn and showed almost no change in facial expression. In the initial assessment the physical

therapist diagnosed that “full extension is impossible because of severe contractures of both knee joints... lower-limb muscle strength is at the F-F+ level on the MMT.” As described above, these contractures limited the robot’s sensors from recognizing gait, so Student B’s quantitative robot data had low reliability and were given little weight in interpretation.

In the first lesson on March 17, Student B showed a refusal reaction on first seeing the robot, saying “It looks a bit scary,” and once she was in a standing position after putting it on, she said “My legs are shaking, I’m scared,” so the session ended after only about five minutes of standing. On April 14, she walked 80 m in the stair-walking mode, saying “I’m not scared anymore,” and on June 5, after walking about 160 m round trip to the water fountain on the third floor in 17 minutes with two rests, she checked the record on the tablet PC screen and set a goal for herself: “Next time I’ll try 200 m.” Meanwhile, the July class report notes that her walking distance decreased from usual because of the hot weather, so the changes in the late phase did not proceed in a straight line.

Indeed, the numerical changes in the BBS (maintained at 7 points) and FAC (maintained at Level 1) were minimal, and the MMT stayed within the initially recorded range, from F-F+ to F+, so Student B was the case with the most limited change in the quantitative indicators. Nevertheless, it was meaningful that through repeated practice of sitting up from a lying position she came to perform it independently at home as well, and that she recovered emotionally. Her guardian stated, “What I’m grateful for is that [my daughter] started to smile again... Now she comes home and tells me about what happened at school.” The homeroom teacher also reported in the July interview, “At the beginning of the first semester, even when she came to school she would just stay quietly at the back of the classroom. But these days, when her friends say ‘Let’s go out to the corridor together,’ she follows them out.” Student B’s case shows that qualitative changes can be observed even amid the technical limitations of the robot data and the limited quantitative changes, and at the same time that quantitative and qualitative data must be interpreted in a way that complements each other.

Student C: Small Steps from Impossible to Possible

Student C, who had relied on a wheelchair for all mobility because of congenital paralysis of the lower limbs, had a quiet but diligent disposition. In the initial assessment the physical therapist diagnosed that she “is in a state of severe muscle atrophy from having hardly used her lower limbs for 18 years... when she attempts to stand with a walker, her knees buckle immediately and she cannot bear her weight.” In the first lesson on March 17, when it was suggested that she put on the robot, Student C said cautiously, “I’m a bit nervous,” and afterward she often answered only “I’m fine” even with an expression that looked strained. Accordingly, from May 19 questions with clear options were used, such as “Which leg feels more tired today?”, and Student C answered “The right one,” confirming that she was able to express her own condition.

Student C began flat-ground walking in April, and on July 14 she “stood up by herself holding the walker... and walked slowly about 5 m over 3 minutes.” On the objective indicators as well, FAC improved from Level 1 to Level 2 and MMT from F to F+, the clearest quantitative change among the three students. The physical therapist analyzed that “the improvement from FAC Level 1 to Level 2 means a qualitative transition from complete dependence to limited independence using a walking aid,” and regarded the student’s diligence as the key factor. Active self-expression also

appeared, such as being the first to say “I’ll try again” in a moment of crisis.

There was a small crisis in early July. On July 3, when Student C, whose expression was gloomy after walker walking, was asked repeatedly, “My knee... I think it hurts a little,” and training was stopped immediately and her guardian was advised to seek a medical examination. In a telephone consultation with the guardian on July 7, it was confirmed that the finding was temporary muscle pain and that, when asked “Do you want to keep going with the robot lessons?”, the student had answered, “Yes, I want to.” On the same day, when a student from the school’s post-secondary vocational program who had come to the AI healthcare room asked, “I heard you’re walking with a robot these days? How is it?”, Student C answered in a long sentence: “At first I was scared, but now it’s fun. It feels amazing to walk.” Student C’s case shows that when advanced assistive technology is combined with a student’s steady effort, it can bring about both a qualitative transition to limited independent walking and inner confidence.



Fig. 2. Student C practicing walker-assisted gait without the robot during the late phase of the program (June to July 2025)

Taking the three cases together, the participating students’ changes were not uniform and the improvements in the quantitative indicators were partial, while the most consistently observed change was in confidence, self-efficacy, and social participation mediated by successful experiences. At the same time, records that ran counter to the success narrative, such as sessions replaced because of poor condition, training volume reduced by hot weather, knee pain, and gait that the sensors failed to recognize, also remained in each case.

Discussion

The Co-teaching Model as a School-based Service Delivery Model

The co-taught lessons in this case were not an itinerant, pull-out service in which the physical therapist takes the student out of the classroom to provide individual therapy, but a collaborative model within the educational context in which the two professionals performed their respective roles within the same session. International research that views the delivery

models of school-based rehabilitation services along a continuum from itinerant to collaborative models embedded in the educational context reports that the more embedded the model, the more communication and mutual professional development between teachers and therapists are promoted, which is advantageous for narrowing the differences between professions (Jeremy et al., 2025), and the Partnering for Change model, in which therapists are regularly present in schools and identify students' needs together with teachers, points in the same direction (Campbell et al., 2023). The division of roles in this case, in which the two professionals simultaneously led different elements, is close to team teaching among the types of co-teaching (Friend et al., 2010). The operation of this model rested on the following conditions: an institutional footing consisting of the MOU, the health management support team, and the timetable and NEIS registration; an explicit division of roles; and joint decision-making in which the robot data were reviewed together. However, in that this collaboration was built on temporary personnel dependent on an MOU and the physical therapist confided that she could not bear responsibility for safety accidents alone, its sustainability must be secured on the basis of the placement of rehabilitation professionals within schools and a system for sharing responsibility (Ahn et al., 2024; Baek et al., 2023).

From Replacement Concern to Augmentation: The Physical Therapist's Shift

The process by which the physical therapist came to perceive the robot, from a threat that replaces jobs to a tool that expands competence, cannot be explained by perceived usefulness and ease of use alone (Park et al., 2022). The triggers of the shift revealed by the data were the experience of witnessing students wearing the robot look at their peers from a new eye level, the change in which Student C came to walk pushing a walker without the robot, and the experience of situations the robot alone could not resolve, such as a student who cried and refused or gait the sensors failed to recognize. The last type of experience in particular allowed her to feel a relationship of complementarity rather than replacement by exposing the robot's limitations and the points at which the therapist's judgment is still needed. This is consistent with an international qualitative study reporting that physical therapists who use exoskeleton robots perceive the devices' benefits, limitations, and workload simultaneously and that actual use depends on facilitating conditions such as time and personnel (Olimb Hillkirk et al., 2025), and with a study reporting clinicians' concerns and caregivers' barriers to access in the adoption of pediatric exoskeletons (Herold et al., 2024). The physical therapist's statement that "the risk is too great to bear alone" and the confirmation, prompted by the knee pain case, of the need for linkage with a medical institution show that technology acceptance is a matter not only of individual attitude but also of facilitating conditions and safety systems, and the report of an adaptation period of about six sessions and mild adverse events in a study of adult patients (Park et al., 2023) also supports the inclusion of early-phase observation and medical linkage in program design.

Why Emotional and Social Changes Appeared First in the School Context

The reason emotional and social changes appeared first while changes in the quantitative indicators were limited can be explained in three ways. First, the most powerful source of self-efficacy is mastery experience achieved directly (Bandura et al., 1997), and this program was structured so that mastery experiences accumulated: small goals, immediate feedback, checking the step count on the tablet PC screen, and early experiences of standing and walking through robot

assistance. The process in which Student A changed from “I can’t run” to “I can do it,” and in which Student B came to set her own goal, “Next time I’ll try 200 m,” corresponds to this. Next, from the perspective that regards participation as both a process and an outcome of intervention (Imms et al., 2017), school is a place where outcomes different from those in hospitals appear first. Student B coming to follow her friends out into the corridor at break time and Student C coming to converse in long sentences with a student from the vocational program are changes in participation that are not captured by MMT, BBS, or FAC, and the experience of standing in the robot and facing peers at the same height appears to have been their starting point. Finally, problems of measurement and training volume acted together in the failure of the quantitative indicators to follow. MMT and FAC are ordinal scales with wide intervals between grades, Student B’s joint contractures limited sensor measurement itself, and whereas the clinical studies that reported improvements in gross motor function applied intensive doses such as 18 sessions over 6 weeks (Choi et al., 2024) or 17 to 20 sessions of 60 minutes each (Kim et al., 2021), this case was operated as two 40-minute lessons per week and included sessions curtailed by the students’ condition and hot weather. The limited quantitative changes in this case therefore show not an absence of effect but that the feasible dose in the school context and the kinds of outcomes that can be expected differ from those in clinical settings (Conner et al., 2022).

Conclusions and Implications

Conclusions

This study qualitatively explored the implementation process and the participants’ experiences of a single case, AI gait rehabilitation robot education operated at one special school. What the case shows can be summarized from the perspective of context and interaction as follows.

First, in this case, AI gait rehabilitation robot education did not come into being through the introduction of the equipment alone but took its place as an educational activity only on the basis of a context consisting of the MOU, the health management support team, the administrative coordination surrounding the timetable and NEIS registration, and the division of roles and mutual adjustment between the two professionals. The boundary between education and therapy was handled institutionally in the form of a related service arranged through consultation with the IEP support team, and in actual lessons in a form in which the special education teacher’s embedded instruction and the physical therapist’s physical intervention coexisted within a single session; this was one practical response to the dilemma that special education teachers face over the boundary between therapy and education (Kim, 2025).

Second, the changes in the perceptions of the special education teacher, the physical therapist, and the guardians arose through interactions in which they witnessed the students’ changes together and jointly overcame crises such as a student crying and refusing, gait the sensors failed to recognize, and knee pain, while tensions such as safety, the sharing of responsibility, the technical limitations of the sensors, and the lack of professional personnel placement remained unresolved.

Third, the participating students’ changes were not uniform, and improvements in the quantitative indicators were often partial or limited to maintenance, whereas changes in confidence, self-efficacy, and social participation appeared

first in the school context, where the teacher, physical therapist, guardians, and peers together created successful experiences and where there were people who watched the students' attempts. This study should therefore be understood not as having verified effectiveness but as having illuminated under what conditions and with what educational meaning AI gait rehabilitation robot education can operate in the school context.

These conclusions point to the possibilities of school-based AI gait rehabilitation robot education together with the conditions for realizing it. The educational potential of advanced assistive technology is not realized automatically; it can become sustainable only on an institutional foundation that includes linkage with medical institutions, a safety system that relieves practitioners' burden, and, above all, the stable placement of rehabilitation professionals within schools.

Limitations

This study has the following limitations. First, because it is an in-depth case analysis of three students at a single special school, the results are difficult to generalize to other settings or to all students with severe and multiple disabilities. In particular, this school was a special environment equipped with a dedicated space and a system of collaboration with external professionals. Second, with a data collection period of about four months (one semester), long-term effects and sustainability are difficult to confirm. Third, there is a possibility of bias arising from the researcher's dual role as program operator and researcher; although the reflexive journal, independent evaluations, and peer debriefing were used to mitigate this, it cannot be ruled out entirely. Fourth, ordinal-scale indicators such as MMT and FAC are unsuitable for arithmetic averaging, and changes in walking time and distance intermingle functional improvement with increases in training volume, so caution is required in interpreting the quantitative data. Fifth, the sensors of the AI gait rehabilitation robot M20 could not reliably recognize gait in the presence of severe joint contractures such as Student B's, which limited the collection of quantitative data and leaves a technical improvement task for application to students with diverse physical conditions. Sixth, the students' experiences were collected in a form mediated by observation logs and the reports of adult participants and are thus at a distance from experiences constructed by the students themselves, and because coding was carried out by the researcher alone with categories confirmed through peer debriefing, no separate codebook or inter-coder agreement was calculated.

Suggestions

First, at the policy and institutional level, support is needed for securing a stable budget, preparing dedicated educational spaces, and maintaining equipment, and above all, a policy review of the reorganization of staffing structures and the securing of positions is required so that rehabilitation professionals such as physical therapists and occupational therapists can be placed in special schools as regular staff.

Second, at the level of educational practice, this education should be expanded into a student-tailored integrated health management system; ways should be found to secure instructional time stably and operate it in an integrated manner in connection with creative experiential activities, the free semester (year) system, and after-school programs; and convergence programs that combine virtual reality and game elements to sustain motivation for participation should be developed.

Third, for future research, the following are required: verification of long-term effects through longitudinal studies; quasi-experimental and randomized controlled studies that compare with conventional physical therapy groups or address differences according to the frequency and intensity of education; in-depth qualitative research focusing on social and emotional changes such as self-esteem and self-efficacy; and research on applicability to diverse disability types and levels of severity. Technical research to improve sensor algorithms so that accurate data can be collected even under diverse physical conditions such as severe joint contractures should be carried out in parallel. In addition, future research is needed that applies methods of collecting the voices of students with severe and multiple disabilities themselves directly, such as interviews mediated by pictures or photographs and response support using augmentative and alternative communication.

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Conflicts of Interest

The authors declared no conflicts of interest.

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