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Tripartite Collaborative Model for Children's Water Environment Science Education: Construction and Practice

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Abstract: To address the problems of fragmented curricula, one-off activities, and an emphasis on knowledge over behavior in current water environment science education for children, this study constructed and implemented a "school-community-enterprise" tripartite collaborative model for children's water environment science education. Targeting children aged 6-12, the model integrates university research expertise, community organizational networks, and enterprise practice scenarios through four mechanisms: joint curriculum development, shared teaching resources, shared practice bases, and joint evaluation of outcomes. A theme-based science curriculum, the journey of a drop of water, was developed, adopting the experience-action-reflection cyclical instructional design. Through an implementation pathway combining on-campus classes, enterprise site visits, and household water-saving actions, the model promotes the translation of children's water environment knowledge into water-saving behavior. Preliminary evidence from classroom observations, parent feedback, and interviews in a pilot study indicates that, beyond knowledge acquisition, children began to spontaneously remind family members to save water and to reuse water for multiple purposes at home. Family and community participation improved simultaneously, and the spillover effect of "educating one child, influencing one family, and engaging one community" began to emerge. The study suggests that in-depth multi-stakeholder collaboration is a feasible pathway to bridging the knowledge-action gap in environmental education, and the resulting curriculum resources and operational framework can serve as a reference for similar science education programs.

Keywords: Child-friendly; Water Environment Science Education; Tripartite Collaboration; Behavior Cultivation; Action Research.

1. Introduction

Water scarcity has become a rigid constraint on China's sustainable development. Transforming Our World: The 2030 Agenda for Sustainable Development lists clean water and sanitation as an independent goal, whose achievement depends not only on engineering and institutional provision but also on a systematic shift in the public's daily water-use behavior [1]. Children are both current users of water resources and future builders of a water-saving society. Article 29 of the Convention on the Rights of the Child establishes "the development of respect for the natural environment" as an educational objective [2], and China's Guiding Opinions on Promoting the Development of Child-Friendly Cities also lists children's participation and environmental experience as important dimensions. In this context, systematic, sustained, and practice-oriented water environment science education for children is a shared requirement of education for sustainable development and child-friendly city development.

In terms of current practice, environmental education for children is mostly delivered through science lectures, facility visits, and picture-book reading, and shows three prominent limitations. First, content is organized in a fragmented manner: activities lack curriculum-based design, making it difficult to support the formation of a complete cognitive structure. Second, implementation is one-off: activities mostly take the form of awareness weeks or themed days, with no sustained follow-up on behavior, so educational effects are hard to maintain. Third, goals emphasize knowledge over behavior: information transmission is the main purpose, and insufficient attention is paid to cultivating children's water-saving behavior [3, 4]. Decades of research on environmental behavior have shown a significant gap between environmental knowledge and environmental behavior; knowledge provision alone is insufficient to induce behavioral change. This conclusion also holds in the context of water environment education. Alongside these content-related limitations, collaboration remains superficial. Although schools, communities, and enterprises are all willing to participate, cooperation in water environment education practice mostly stays at the level of "visit plus lecture" [5]: schools lack authentic contexts and professional materials, communities lack curricular content and mobilization tools, and enterprises possess process scenarios but lack the capacity to transform them into educational offerings. The resources of the three parties have not formed deeply coupled mechanisms of joint curriculum development, shared teaching resources, shared practice bases, and joint evaluation of outcomes.

Accordingly, this study focuses on the following questions: how to construct a "school-community-enterprise" tripartite collaborative model for children's water environment science education; and whether this model can promote the development of children's cognition, emotion, and behavior regarding the water environment and, by engaging children, drive family and community participation to produce an observable spillover effect.

2. Theoretical Foundations

2.1. The Knowledge-action Relationship in Environmental Education

The starting point of research on the effectiveness of environmental education is the analysis of the knowledge-behavior relationship. A meta-analysis of 128 studies by Hines et al. found that behavioral intention was most strongly associated with behavior, whereas the associations of knowledge and attitude with behavior were relatively limited; on this basis they proposed a model of responsible environmental behavior in which behavioral intention is the direct antecedent of behavior, and intention itself is shaped jointly by action skills, strategic knowledge, attitudes, locus of control, and personal responsibility [6]. Hungerford and Volk further argued that if environmental education is to change learners' behavior, it must intervene in all of these variables rather than remain at the level of factual knowledge transmission [7]. Based on an action orientation, Jensen proposed the concept of "action competence," defining the goal of environmental education as learners' capacity to make and carry out environmental decisions [8]. Kollmuss and Agyeman systematically reviewed the internal and external barriers between intention and behavior, emphasizing the constraints imposed by social norms and situational conditions on behavior implementation [9]. These studies suggest that water environment science education must simultaneously design four channels-cognition, emotion, behavior, and context-and that none can be omitted.

2.2. Theoretical Basis for Behavior Cultivation

The theory of planned behavior provides an analytical framework for behavior promotion strategies [10]. The theory holds that behavioral intention is determined by behavioral attitude, subjective norm, and perceived behavioral control, and that intention together with perceived control predicts behavior. For children's water-saving behavior, the attitude channel corresponds to scientific and engaging curricular content; the norm channel corresponds to the joint participation of peers and family; and the control channel corresponds to low-threshold action tools and process-based feedback. Stern's comprehensive theory further emphasizes the interaction between personal norms and situational conditions [11], suggesting that transforming family and community contexts can provide external support for behavioral change. This inference forms the theoretical basis for extending the educational setting of this study from schools to communities and enterprises.

2.3. Childhood Experience and Experiential Learning

Developmental psychology evidence shows that positive childhood experiences of interacting with nature are an important predictor of pro-environmental behavior in adulthood [12]. Otto and Pensini's empirical study of children found that environmental knowledge is significantly associated with ecological behavior only when combined with connectedness to nature [13]. Experiential learning research likewise supports the value of direct experience: compared with indirect experiences such as pictures and explanations, hands-on experiments and field trips have a more pronounced effect on promoting environmental knowledge and behavioral intention [14]; place-based learning helps enhance children's environmental awareness and sense of place [15]; and a systematic review of outdoor learning confirms the combined benefits of out-of-classroom learning for knowledge, attitudes, and social development [16]. These findings jointly support the design orientation of incorporating water treatment scenarios and hands-on inquiry into the children's water environment curriculum.

2.4. Research Gaps

Taken together, the existing literature still has three gaps. First, in terms of theme, there are few intervention studies on children's science education that focus on water environment issues and cover the complete chain of "classroom-practice base-home." Second, in terms of organization, research on in-depth multi-stakeholder collaborative mechanisms for children is almost nonexistent; existing collaboration mostly remains at the level of resource stacking. Third, in terms of goals, science education models that take behavior cultivation and family spillover as direct objectives, combined with sustained feedback mechanisms, lack systematic exploration. This study addresses these gaps.

3. Construction of the Tripartite Collaborative Model

3.1. Design Rationale

The model design follows three lines of thinking. First, children are regarded as catalysts of household behavior change. The family is the primary context of children's daily life and the smallest unit in which water-use behavior occurs; by educating children to leverage the joint participation of family members, the educational effect can be multiplied through spillover. Second, the model benchmarks three-dimensional learning objectives. Referring to UNESCO's framework of learning objectives for education for sustainable development, the cognitive, social-emotional, and behavioral dimensions are integrated throughout the curriculum [17]. Third, in-depth collaboration replaces superficial stacking: tripartite collaboration is not a simple combination of resources, but a reconstruction of the division of labor and workflows around a shared educational goal, so that all four link-curriculum, teaching staff, scenarios, and evaluation-form substantive intersections.

3.2. Four Collaborative Mechanisms

Based on visits to one primary school, one community, and two water utilities, and through multi-party discussions, the research team distilled four mechanisms supporting the operation of the model (Figure 1). For joint curriculum development, the university research team leads the development of curriculum standards and lesson plans, primary school teachers adjust teaching procedures according to student conditions, and enterprise engineers transform real process cases into inquiry materials understandable to children; the three parties conduct joint teaching research every semester. For shared teaching resources, a mixed teaching team is formed consisting of university teachers, primary school teachers, enterprise mentors, and university student science outreach volunteers; enterprise engineers, after training in science communication, take on site interpretation and experiment instruction at the practice bases. For shared practice bases, enterprise wastewater treatment plants and waterworks are regularly opened to pilot schools, while community activity rooms and publicity facilities serve as extended venues for water-saving actions and achievement

exhibitions. For joint evaluation of outcomes, the university designs pre- and post-test questionnaires and interview outlines, the primary school provides classroom observation records, enterprises provide visit data, and the community collates household check-in records; all data are reviewed at joint meetings each semester to jointly drive curriculum iteration.

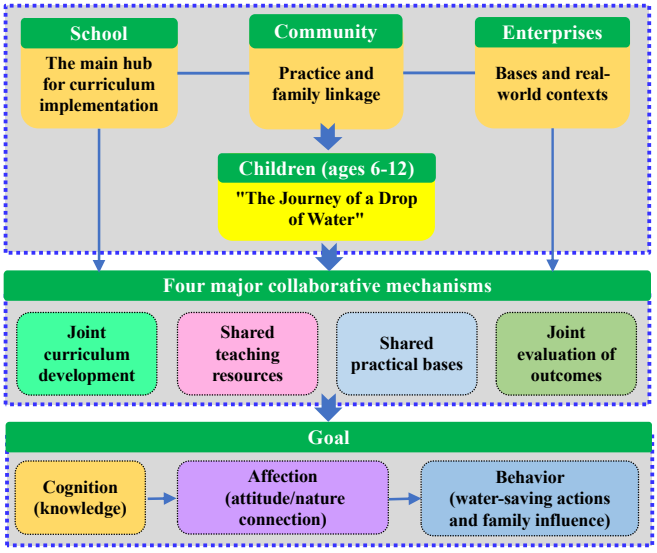


Fig 1. Collaborative education framework

3.3. Safeguards for Sustainable Operation

The sustainability of the model depends on the institutionalized alignment of the three parties' demands. For schools, the model provides a systematic school-based science curriculum and teaching staff support that can be directly embedded in science courses and after-school services. For communities, the model provides a low-cost carrier for resident mobilization, helping to build a child-friendly activity brand. For enterprises, the model fulfills social responsibility at low cost while gaining reciprocal support from the university in science material development and talent training. Project funds are only used for necessary expenses such as questionnaire printing, science materials, and transportation and labor allowances; enterprise reception for site visits is supported by partner organizations as a public service. The model is therefore low-cost and replicable.

4. Development of "The Journey of a Drop of Water" Curriculum

4.1. Needs Analysis and Curriculum Positioning

Before curriculum development, the research team conducted teacher interviews and classroom observations at the intended pilot school, as well as needs-based discussion sessions with community workers and parents. The results showed that younger children, who are dominated by concrete thinking, are suited to story-based and game-based content organization, whereas middle- and upper-grade children have already developed preliminary quantitative thinking and experimental operation skills and can carry out simple water-use surveys and controlled experiments. Accordingly, the curriculum was designed for children aged 6-12, with the same theme recurring at different depths across grade levels to form a spiraling content structure.

4.2. Curriculum Structure

The curriculum takes "The Journey of a Drop of Water" as its narrative thread, organizing the science of the water cycle, household water accounting, wastewater treatment processes, and water-saving actions into four progressive modules (Table 1): Module 1, "The Secret of Water," teaches the science of the water cycle in on-campus classes; Module 2, "Household Water Footprint," guides students to record and account for household water use and to map their household water footprint; Module 3, "From Wastewater to Clean Water," is completed at the enterprise base through a water plant visit and comparative filtration experiments; and Module 4, "Little Water Guardians," launches a 21-day household water-saving check-in through the community. The four modules correspond successively to cognitive foundation, contextual transfer, direct experience, and behavior consolidation, constituting a complete learning progression.

Table 1. Module design of "The Journey of a Drop of Water" curriculum

Module	Theme	Main activities	Venue and instructors	Learning outcomes
Module 1	The Secret of Water	Water cycle demonstration; simulation experiments	On-campus classroom / primary school teachers	Water cycle concept map
Module 2	Household Water Footprint	One-week water-use recording; water footprint mapping	Home/children and parents working together	Household water footprint map
Module 3	From Wastewater to Clean Water	Water plant visit; comparative filtration/coagulation/adsorption experiments	Enterprise base/engineer mentors	Experiment observation records
Module 4	Little Water Guardians	Community water-saving initiative; 21-day household check-in	Community and home/mixed teaching team	Water-saving behavior records

4.3. The Experience-Action-Reflection Instructional Design

To address the knowledge-action gap, each module embeds an experience-action-reflection cycle (Figure 2): authentic or simulated direct experience activates learning interest and emotional engagement; an achievable micro-action task is then assigned; and timely feedback is provided through work exhibitions, data sharing, and class presentations. Taking Module 3 as an example, after completing the filtration experiment, students upload comparative photos of the water samples before and after filtration to the class group, which are jointly reviewed by the teacher and the engineer. In Module 4, class feedback sessions are scheduled on Days 7 and 14 of the check-in, and a "Little Water Guardian" badge is awarded to sustain behavioral engagement through social reinforcement. This design systematically embeds the motivation, ability, and prompt elements required for behavior change into the teaching process.

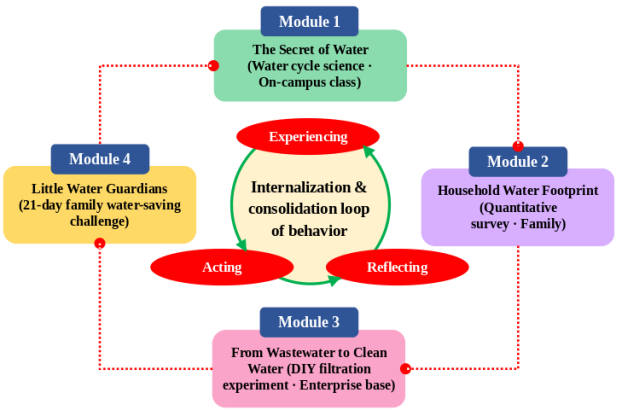


Fig 2. Curriculum modules and the experience-action-reflection cycle design

5. Pilot Practice and Effects

This study adopts an action research paradigm, advancing spirally through the procedures of design, implementation, observation, reflection, and iteration (Figure 3). To date, the research team has completed a pilot study in a primary school in Chengdu (12 families), fully implementing the intervention process of "two class sessions, one water plant visit, and a 21-day household water-saving check-in" to test the smoothness of the curriculum process and the applicability of the research instruments, thereby providing a solid basis for the subsequent formal pilot. The study followed ethical norms: participating families all signed informed consent forms, and the data were anonymized. It should be noted that the findings presented in this section come from classroom observations, parent feedback, and semi-structured interviews with teachers, community workers, and enterprise mentors; they are qualitative data intended to present the concrete manifestations and mechanisms of behavioral change, while quantitative verification of the effects awaits the controlled study of the formal pilot.

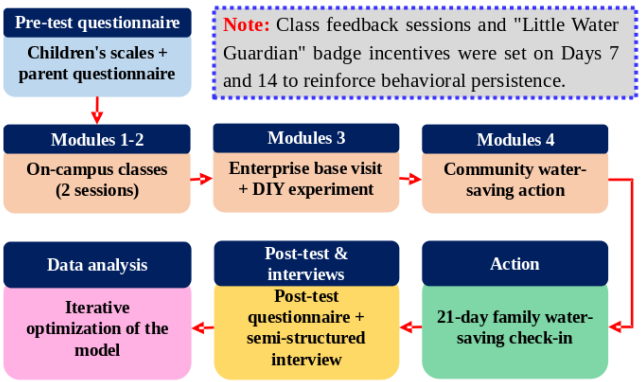


Fig 3. Pilot implementation process

Classroom observations showed that experiential segments effectively stimulated children's inquiry interest. In the simulation experiments of "filtration," "adsorption," "coagulation," and "activated sludge" [18-21], children asked questions continuously around the experimental setups; during the water plant visit, the sedimentation tanks and aeration processes attracted widespread attention, and some children were able to recount the main steps of wastewater treatment after the visit. The transfer effect of hands-on experiments was particularly evident: in interviews, some parents reported that their children spontaneously repeated the filtration experiment at home with simple materials and demonstrated the procedure to their grandparents.

Behavioral changes at home constitute more substantial evidence. During the 21-day check-in, parent feedback focused on two aspects. The first was water-use reminders: several parents mentioned that their children began to proactively remind family members to shorten shower times and to turn off taps promptly-the water-saving reminder shifted from an adult demand to a child's spontaneous behavior. The second was multi-purpose water reuse: in some families, under the children's insistence, fixed practices such as mopping floors and watering flowers with laundry water were established, with the children acting as supervisors. Regarding the decline in participation enthusiasm that occurred during the check-in, the relevant families generally resumed check-ins after the class feedback sessions and badge incentives, indicating that periodic feedback plays a practical role in behavior maintenance.

Teachers' feedback focused on the operability of the curriculum and its spillover effects. The interviewed teachers considered the curriculum structure complete and directly embeddable in science courses and after-school services, which reduced the lesson-preparation burden of science content; they also noted that the teaching effects extended beyond school through children's family communication. Community workers reported that water-saving mobilization with children as the link showed significantly higher participation than previous activities targeting adults, and the community is considering incorporating "Little Water Guardians" as a standing agenda item in the children's council. Enterprise mentors believed that explaining processes to children required engineers to transform technical knowledge into plain language, a process that enhanced the enterprises' public communication capacity; the enterprises were willing to make the regular opening of their bases a long-term arrangement.

The pilot also exposed several problems, providing an improvement basis for the formal pilot: participation enthusiasm declined in the middle and late stages of the check-in, so the frequency and form of feedback incentives need to be increased, and mechanisms such as family pairing and community points could be considered; some parents regarded the check-in as the child's task alone and participated to a limited extent, so follow-up activities will design water-saving tasks requiring whole-family collaboration to shift parents' role from supervisor to participant; and the curricular content was somewhat difficult for younger children, so the lower-grade version needs more game-based elements.

Considering the changes at both the family and community levels, the outline of the spillover effect has emerged (Figure 4). At the family level, water saving shifted from adults' repeated demands to children's proactive persistence, and parents shifted from being educated to being companions. At the community level, one-off activities settled into a sustainable children's council project, and children began to participate in public affairs as community members. At the school level, the mixed teaching team and site visits were transformed into reusable school-based curriculum resources. These three levels of change reinforce one another, providing preliminary empirical evidence for "educating one child, influencing one family, and engaging one community".

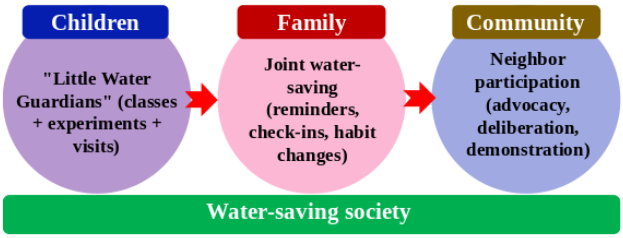


Fig 4. Spillover pathway of children's water environment education

6. Summary

In-depth "school-community-enterprise" tripartite collaboration is a feasible organizational approach to overcoming fragmentation and superficiality in children's water environment science education; joint curriculum development, shared teaching resources, shared practice bases, and joint evaluation of outcomes constitute the basic replicable mechanisms of the model. The "Journey of a Drop of Water" curriculum and the experience-action-reflection cyclical design can connect the cognitive, emotional, and behavioral dimensions, promoting children's progression from "knowing" to "doing." Children can effectively drive changes in household water-saving behavior, and the preliminary evidence of the spillover effect indicates that this pathway merits further verification.

Based on these conclusions, the following recommendations are proposed. At the school level, such curricula should be incorporated into science education and after-school services, with regular teaching research mechanisms established with universities and enterprises. At the community level, children's water-saving actions should be embedded in resident deliberation and volunteer service systems to leverage children's linking role. At the enterprise level, science education bases should be operated as long-term social responsibility projects, accompanied by training in engineers' science communication capacity. At the policy level, it is recommended that a special item for participatory environmental education for children be added to the evaluation indicators of child-friendly city development, and that high-quality curriculum resources be shared across regions through government service procurement. Follow-up research will complete the formal pilot and a three-month follow-up measurement, compile an operational guide for tripartite collaboration and a curriculum resource package, and conduct multiple rounds of practice across different grade levels and regions to test the applicability boundaries of the model.

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